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ORIGINAL ARTICLES.

I. — Woodwardian Museum Notes: Salter's Undescribed Species. IX.[1]

By F. R. Cowper Reed, M.A., F.G.S.

(PLATE XVIII.)

Monticulipora (Monotrypa) poculum, Salter. (Pl. XVIII, Figs. 1–3.)

1873. *Monticulipora poculum*, Salter MS.: Cat. Camb. Sil. Foss. Woodw. Mus., p. 109 (*a* 314).

1891. *Monticulipora* (?) *poculum*, Woods: Cat. Type Foss. Woodw. Mus., p. 25.

There are eight specimens (*a* 314) to which Salter gave this name. All are from the Wenlock Limestone of Dudley, and belong to the Fletcher Collection. Only one shows any part of the upper surface.

Diagnosis.—Corallum circular, broadly cup-shaped or crateriform, sharp-edged, thin. Cup shallow, concave. Base convex, broadly conical, attached by apex, covered by thick concentrically wrinkled epitheca marked with fine radiating striæ, and in some cases furnished with a few short root-like processes on the sides. Corallites radiating from centre of base, regular, hexagonal or polygonal, of equal or subequal size, thin-walled, crossed by a few horizontal or oblique tabulæ. Minute, thick-walled tubuli ('spiniform corallites') present, usually one at each angle of junction of adjacent polygonal corallites.

Measurements.

	I	II	III	IV
	mm.	mm.	mm.	mm.
Diameter of corallum	30	27	16	15
Height of ditto	8	10	7	6

Remarks.—The peculiar shape of the corallum, the thick striated epitheca, and short corallites separate this species from *M. discoidea*,[2] James, to which it has several points of resemblance, i.e., the thin-walled subequal corallites, the epithecal cover, the spiniform corallites, and the absence of monticules. The 'spiniform corallites' are not quite so abundant in Salter's species as in *M. discoidea*, and

[1] For previous articles see Geol. Mag., 1901, pp. 5, 106, 246, 355, and 576; 1902, pp. 122, 145, and 256.

[2] Nicholson: Struct. and affin. genus *Monticulipora*, 1881, p. 193, and references.

the other corallites are relatively larger than Nicholson's figure (op. cit., pl. iv, fig. 3*c*) indicates.

TRACHYPORA (?) SEELEYI, Salter. (Pl. XVIII, Figs. 4, 5.)

1873. *Alveolites Seeleyi*, Salter MS.: Cat. Camb. Sil. Foss. Woodw. Mus., p. 107 (*a* 365).
1891. *Alveolites Seeleyi*, Woods: Cat. Type Foss. Woodw. Mus., p. 13.

The original specimen (*a* 365) consists of a fine branching corallum from the Wenlock Limestone of Dudley (Fletcher Collection), and is in an excellent state of preservation.

DIAGNOSIS. — Corallum ramose, subdividing into many small irregularly dichotomous, cylindrical, or flattened lobate branches, averaging 4 mm. in diameter, irregularly anastomosing, and covered with closely set small corallites in irregularly oblique or vertical rows, but mostly without any definite arrangement. Corallites subcircular or polygonal, subequal in size, and usually numbering 5–6 across the width of a branch 4 mm. in diameter. Corallites run obliquely outwards from axis, but meet outer surface at right angles. Cell-walls thick, strongly granulated and punctated on surface of corallum, measuring from $\frac{1}{4}$ to $\frac{1}{2}$ the diameter of the calices. Calices cup-shaped and circular owing to thickening of cell-walls, with small circular hole at bottom as in *Striatopora*. Walls of corallites thickly set with minute mural pores. Tabulæ present?

REMARKS.—It is somewhat difficult to assign this species to its proper generic position. The calices in their characters remind us of *Striatopora*,[1] the thickened cell-walls and closely set corallites of *Cladopora* (Hall & Rominger),[2] but the granulation of the walls on the surface between the calices is a characteristic feature of *Trachypora*.[3] In this genus *Trachypora* (*Dendropora*, according to Rominger, op. cit., includes it) the calices are usually much further apart, but it is doubtful if this is more than a specific character. The peculiar cup-shaped orifice is not limited to *Striatopora*, and the radiating striæ which are present within it in that genus are here wanting. It is quite distinct from *Alveolites*. No species of *Trachypora* has hitherto been definitely found in Wenlock beds, but Nicholson (op. cit., p. 106) declared that he possessed a specimen from this horizon indistinguishable from *Dendropora*.

INCERTÆ SEDIS.

PASCEOLUS (?) HOSPITALIS (Salter). (Pl. XVIII, Figs. 6, 7.)

1873. *Sphærospongia hospitalis*, Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 40.
1878. *Sphærospongia hospitalis*, Nicholson & Etheridge: Mon. Girvan Silur. Foss., fasc. i, pp. 10–18 (mentioned as allied to *Nidulites* and *Pasceolus*).
1884. *Sphærospongia hospitalis*, G. J. Hinde: Q.J.G.S., vol. xl, p. 835 (mentioned as probably related to *Pasceolus*).

[1] Hall: Pal. N.Y., vol. ii (1852), p. 156. Rominger: Geol. Surv. Michigan, vol. iii, pt. 2 (1876), p. 58. Nicholson: Tabulate Corals (1879), p. 97.
[2] Hall: op. cit., p. 137. Rominger: op. cit., p. 46. Nicholson: op. cit., p. 79.
[3] Rominger: op. cit., p. 61 [*Dendropora*]. Nicholson: op. cit., p. 102. Frech: Leth. Geog., Th. i, Bd. 1 (1897), p. 437.

1888. *Sphærospongia hospitalis*, G. J. Hinde: Mon. Brit. Foss. Sponges (Palæont. Soc.), p. 182.
1888. *Sphærospongia hospitalis*, Etheridge: Cat. Brit. Foss., pt. i, p. 3.
1891. *Sphærospongia hospitalis*, Woods: Cat. Type Foss. Woodw. Mus., p. 2.
1880–97. *Sphærospongia hospitalis*, Roemer (Frech): Leth. Geog., Th. i, Bd. 1, p. 296.

The original specimen, which came from the Middle Bala of the Onny River, is unfortunately missing, as Mr. Woods (op. cit. supra) mentions. But we possess four other specimens in the Woodwardian Museum from the same locality and horizon, two of which date back to Salter's time. Two of these specimens are external casts of the surface, and the other two show the surface itself, one being a nearly complete individual.

Diagnosis.—Body globular or ovoid; base or stalk unknown. Surface composed of numerous closely fitting, convex, hexagonal plates, about 1·5 mm in diameter. Each plate has its individual convexity, and is ornamented with small irregular radiating ridges, particularly distinct near the edges of the plates. The centre of many of the plates is seen to be marked by a small tubercle, but it is generally very indistinct. No different plates nor openings visible, but indications of closely placed radiating pillars inside the body.

Measurements.—Diameters of ovoid figured specimen, 30 mm. and 25 mm.; five plates in a space of 8 mm.

Remarks.—The affinities of this species have been briefly mentioned by Nicholson, Etheridge, and Hinde in the references above given. The probable relations to *Pasceolus* are generally recognized in the shape, character of surface, and ornamentation of the plates; but some doubts must remain as to the true generic position of this species until we are better acquainted with its internal structure. Hinde (op. cit.) has declared that it cannot be left in the genus *Sphærospongia*, of which *Sph. tessellata* (Phill.) is the type.

Graptotheca catenulata, Salter. (Pl. XVIII, Fig. 8.)

1873. *Graptotheca catenulata*, n.sp., Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 171 (*a* 986).
1891. *Graptotheca catenulata*, Woods: Cat. Type Foss. Woodw. Mus., p. 120.

There is only Salter's original specimen (*a* 986) of this curious fossil, which he attributed to the Pteropoda, giving the new generic name of *Graptotheca*. This genus is not mentioned by Zittel or in any subsequent palæontological work, so far as I am aware. It is difficult to see why Salter assigned it to such a zoological position, as it exhibits no peculiarly pteropodal characters. The specimen is from the Lower Ludlow of Leintwardine, and is of an elongated subtriangular form, acutely pointed at one end, the two adjacent sides making an angle of about 30°. The other end is broad, but its true shape cannot be made out owing to the poor state of preservation. The surface is marked with 8 or 9 strong raised lines parallel to the second longest side; of these the first 4 or 5 nearest the margin are equidistant, but the others are less regular and slightly curved. Some of the lines bifurcate near

the broader end. The upper edge appears to be curved over. The total length of the specimen is about 70 mm., and the width at the broader end about 35 mm. It appears possible that it may be really the crushed ventral shield of a *Scaphaspis* (*Cyathaspis*). The ornamentation is somewhat similar, and an obliquely crushed specimen of *Scaphaspis ludensis*[1] which occurs on the same horizon and at the same locality would present a somewhat similar appearance. But it is even very doubtful to what group we should properly assign this ill-defined and unsatisfactory fossil.

Favospongia Goughi, Salter.

1854. Undetermined fossil, McCoy: Brit. Pal. Foss., pl. i D, figs. 9, 9*a*.
1873. *Pasceolus Goughi*, Salter: Cat. Camb. Sil. Foss. Woodw. Mus., p. 175 (*b* 53, *b* 54: reference to McCoy's figures).
1878. Sponge (?): Cat. Camb. Sil. Foss. Mus. Pract. Geol., p. 128.
1887. *Favospongia Ruthveni* (Salter MS.), G. J. Hinde: Brit. Foss. Sponges (Palæont. Soc.), pt. ii, p. 179.
1888. *Favospongia Ruthveni*, Etheridge: Cat. Brit. Foss., pt. i, p. 2.
1888. *Pasceolus Goughi*, Etheridge: ibid., p. 2.
1888. *Pasceolus Goughi*: Mem. Geol. Surv. Geology of Kendal, etc., 2nd ed., Table ii, p. 60 (specimens in Kendal and Woodwardian Museums from Kirkby Moor Flags of Benson Knot).
1891. *Pasceolus Goughi*, Woods: Cat. Type Foss. Woodw. Mus., p. 2.
1897. *Pasceolus Goughi*, Roemer: Lethæa Geognostica, Th. i, Bd. 1, p. 296.

There are four specimens of this form labelled by Salter *b* 53, *b* 54, all of which are from the Kirkby Moor Flags of Benson Knot. They were figured by McCoy (op. cit. supra) as an "undetermined fossil," but not described by him. Salter, in his Catalogue (loc. cit. supra), places McCoy's figures in the margin opposite the reference to these specimens which he calls *Pasceolus Goughi*, and merely notes that "the genus has been described by Billings from Canada." McCoy had only remarked in the reference to the figures on his plate that the fossil was common in the Upper Ludlow rocks of Kendal.

Dr. Hinde (op. cit. supra), in mentioning the problematical *Favospongia Ruthveni*, refers to these figures given by McCoy as representing this latter species, but does not state that they were designated *Pasceolus Goughi* by Salter in 1873.

There has thus been considerable confusion about this form. In the first place, our Woodwardian Museum specimens are undoubtedly those figured by McCoy in 1854 and referred to by Salter in 1873 as *Pasceolus Goughi*; secondly, the name *Favospongia Ruthveni* appears first, as Dr. Hinde informs me, in John Morris' own interleaved copy of his "Catalogue of British Fossils" (ed. 1854) as a manuscript entry in Morris' own hand on an interleaf amongst the Amorphozoa in the following way :—

> "Favospongia, Salter, 1861.
> Danbyi, *Tetragonis*.
> Ruthveni, Salt.: M.G.S., p. 136.
> Pal. Fo. W. M., Pl. i D, fig. 9."

This entry is apparently meant to record the occurrence of *Favospongia Ruthveni* and *Tetragonis Danbyi* (the latter of which

[1] Lankester: Mon. Old Red Sandst. Fishes (Palæont. Soc.), 1868, p. 25, pl. ii, figs. 4, 4*a*.

McCoy figured and described in his Synopsis). The date 1861 appears to point to Salter having created the genus *Favospongia* in that year, and the reference to McCoy's figures of an "undetermined fossil" that he applied the name to this form. But Dr. Hinde has not been able to find out to what "M.G.S., p. 136" refers, and the designation of the fossil as *Favospongia Ruthveni* does not seem to have appeared in print before the name *Pasceolus Goughi*.

Six specimens, Dr. Hinde informs me, in the Geological Society's Museum, Burlington House, are mounted on one tablet and labelled "*Favospongia Ruthveni*, Salter; Upper Ludlow Rock, Benson Knot," but the writing is not in Salter's hand. Another tablet with a single specimen is marked (apparently in the same handwriting as the other) "*Favospongia* (a sponge), Upper Ludlow, Kendal, Professor Sedgwick, Figd. in Synopsis." The specimen in the Jermyn Street Museum entered as 'sponge' in the Catalogue (loc. cit.) is inscribed on the back "Collected by Ruthven from Upper Ludlow at Benson Knot," and Dr. Hinde informs me that it is the same form as that named *Favospongia Ruthveni* in the Geological Society's Museum. Unfortunately nothing further is known about this Jermyn Street specimen.

Finally, Dr. Hinde has kindly compared the Cambridge specimens labelled *Pasceolus Goughi* with these in London, and states that there is no doubt that they are identical, and that it is the same form to which the two names *Pasceolus Goughi* and *Favospongia Ruthveni* have been given.

As to the correct generic name to adopt, Dr. Hinde is of the opinion that "both are alike unsuitable, for *Favospongia* implies that it is a sponge, which in my opinion it is not; and *Pasceolus* that it belongs to Billings' genus, and this again is highly doubtful, though less improbable than its sponge affinities." Dr. Hinde writes further that on comparison with genuine specimens of Billings' *Pasceolus* collected from Anticosti, he does not think that *F. Ruthveni*=*P. Goughi* should be included in Billings' genus.

It appears to me advisable to adopt the generic name *Favospongia* in preference to *Pasceolus*, firstly, because it does not commit one to identifying this form with Billings' genus, to which it appears that it does not probably belong; and secondly, because the name *Favospongia*, in spite of its objectionable suggestion of affinity with sponges, has not been applied to any other fossil,[1] and is practically a new name including only this one species. The specific name *Goughi*, having appeared in print before that of *Ruthveni*, must, however, be adopted. We must wait for further knowledge of the structure of this form to determine its true affinities, and if it has ultimately to be assigned to some previously established genus the name *Favospongia* must be dropped. For the present, however, it serves the useful purpose of designating a peculiar fossil which cannot be placed with certainty in any well-defined genus. The description of its characters is necessarily meagre.

[1] Zittel in his Handbook of Palæontology does not give it.

Diagnosis.—Body hemispherical; base flattened, slightly convex in middle as if for attachment. Whole surface, including base, covered with a reticulating network of polygonal cells of irregular shape and unequal size; many are hexagonal or pentagonal, and in one specimen (*b* 53) they are subequal in size. General superficial appearance resembles *Favosites*. No internal structure known.

Measurements.—Diameter of most perfect specimen, 30 mm.; height, 17 mm.

EXPLANATION OF PLATE XVIII.

Fig. 1.—*Monticulipora poculum*, Salter. Wenlock Limestone: Dudley. Fletcher Collection. × 1½.
,, 2.—A part of the same, showing longitudinal section near margin. × 10.
,, 3.—A part of the same, showing spiniform and polygonal corallites. × 10.
,, 4.—*Trachypora* (?) *Seeleyi*, Salter. Wenlock Limestone: Dudley. Fletcher Coll. × 2.
,, 5.—A part of the same. × 5.
,, 6.—*Pasceolus* (?) *hospitalis* (Salter). Middle Bala: Onny River. × 1½.
,, 7.—A part of the same. × 4.
,, 8.—*Graptotheca catenulata*, Salter. Lower Ludlow: Leintwardine. Nat. size.

II.—Note on *Nautilus robustus*, Foord & Crick.

By G. C. Crick, F.G.S., of the British Museum (Natural History).

The species *Nautilus robustus* was founded[1] by Dr. Foord and myself upon three examples in the British Museum collection, bearing respectively the register numbers 37,010, 37,005, and C. 1,944.

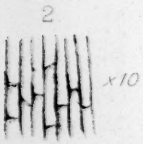
The specimen numbered 37,010 was regarded as the type (see accompanying Figures). It originally formed part of the Tesson Collection, and is stated to be from the "Inferior Oolite, Les Moutiers, Normandy." The horizon, however, given by us in our original description, and subsequently also by Dr. Foord in his "Catalogue of the Cephalopoda in the British Museum (Natural History)," vol. ii, pp. 205-7, is "Upper Lias."

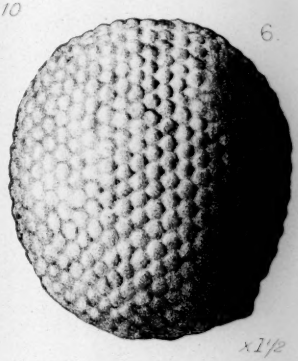
The example bearing the number 37,005 belonged also to the Tesson Collection, and was labelled "*Nautilus inornatus*, d'Orb. Lias supérieur, Curcy." The third specimen, which is numbered C. 1,944, lacks any information as to the horizon and locality whence it was obtained, but it is probably a British fossil.

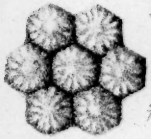
Quite recently Mr. S. S. Buckman informed me that there were two examples of this species in the Cheltenham College Museum, and through the kindness of the authorities of the College, to whom I desire to express my sincere thanks, the specimens have been sent to me for examination, so that I have been able to compare them with the type-specimen. The larger specimen is labelled in Mr. S. S. Buckman's handwriting, "Marlstone. Loc: unknown; but probably near Cheltenham, and possibly Alderton Hill."[2] The

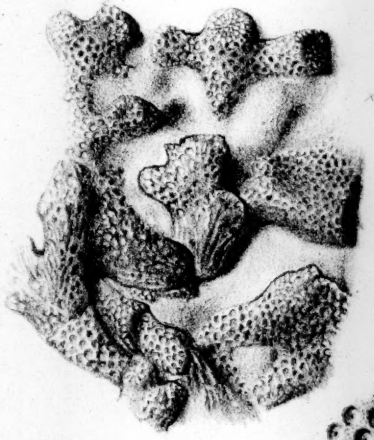
[1] A. H. Foord & G. C. Crick: Ann. & Mag. Nat. Hist., ser. vi, vol. v (1890), p. 271, fig. 5.

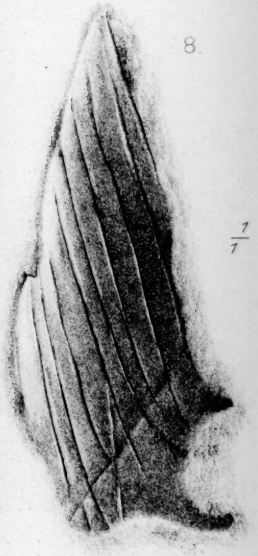
[2] Mr. Buckman tells me that this is "perhaps the *Nautilus obesus* mentioned in 'Geology of Cheltenham,' ed. 2, p. 40."







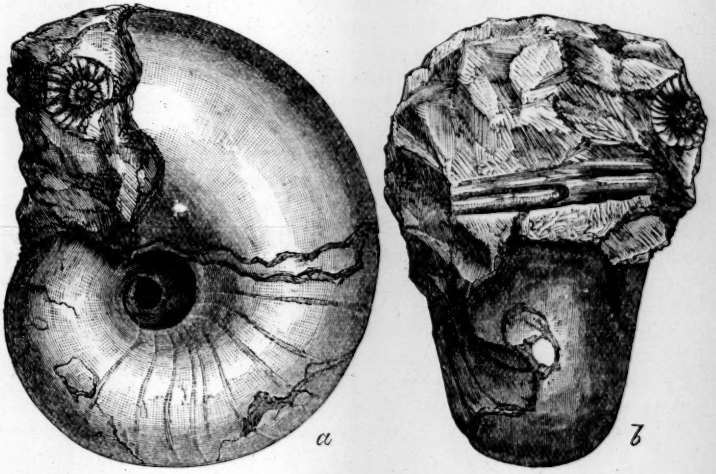




G.M. Woodward del. et lith. West, Newman imp.

Silurian Fossils, *Woodwardian Museum*.

other specimen bears an original label with the inscription "Nautilus, Marlstone. Gretton."[1] Fully agreeing with Mr. Buckman's identification of these specimens, I was led to enquire into the geological age of the examples in the National Collection, for if the Cheltenham College specimens are correctly identified, it would seem that the species belongs to the Marlstone or Middle Lias, rather than to either the Upper Lias or to the Inferior Oolite.



Nautilus robustus.—*a*, lateral view, showing the cast of part of the body-chamber, the test being present in the septate part of the shell, where a few lines of growth are indicated; *b*, front view. Middle Lias: Les Moutiers, Normandy, France. Drawn from the type-specimen in the British Museum collection [No. 37,010]. Rather less than one-third natural size.

As already stated, one of the examples on which the species was founded, viz., the specimen in the British Museum bearing the register number C. 1,944, lacks any information respecting the horizon and locality whence it was obtained. Its matrix, however, agrees with that of the specimen in the Cheltenham College Museum that is labelled "Marlstone. Loc: unknown; but probably near Cheltenham, and possibly Alderton Hill." It is therefore more than probable that this fossil is a British specimen, and that it came from the Marlstone.

As mentioned above, the specimen regarded as the type, and figured, originally formed part of the Tesson Collection. It has the following measurements: diameter (without test near aperture), 204 mm.; thickness (without test on each side), 136 mm.; width of umbilicus (test present on each side), 33 mm. One-third of the last whorl is occupied by the body-chamber. The specimen does

[1] In regard to this specimen Mr. Buckman writes me as follows: "The label is one of my father's; the writing on it is very similar to his. Many specimens in the Museum were presented by my father, and it is therefore quite likely that he collected this specimen himself."

not bear an original label, but is numbered 37,010, and has been registered as "Nautilus sp., Inferior Oolite, Les Moutiers, Normandy." As stated in the remarks appended to the original description of the species by Dr. Foord and myself, a figure of the type-specimen was submitted to Dr. Paul Fischer, of the Museum of Natural History, Paris, who kindly replied to the effect that he found no form either in the Museum of Natural History, the Museum of the École des Mines, nor in that of the Sorbonne, which could be identified with certainty with our specimen. He observed that it resembles perhaps some specimens of *Nautilus Toarcensis*, d'Orb., but that the umbilicus in the latter appears more open and the aperture more dilated, remarks with which we fully concurred. The affinities of the species being nearest to *Nautilus Toarcensis*, d'Orb., from the Upper Lias, and the specimen numbered 37,005, being apparently specifically identical and bearing an original label indicating that it came from the Upper Lias, it seemed most probable that the new species belonged to the Upper Lias. But there are portions of other fossils preserved in the matrix, among them being a portion of a Belemnite, and a fairly good impression of an Ammonite (see Figures). A plaster squeeze of this Ammonite was taken, and submitted—the specimen being registered as from the "Inferior Oolite"—to Mr. S. S. Buckman for his opinion, and he very kindly replied as follows:—"It is certainly a *Paltopleuroceras*, and is nearest to *Am*: *costatus nudus*, Quenst. Jura, Pl. 21, f. 3, which Hyatt made type of his *Pleuroceras pseudocostatum*, Bull. Mus. Comp. Zool. Foss. Ceph. No. 5, p. 90, 1867. It is also near to the specimen figured by Quenst[edt] Schwäb. Amm. Pl. 42, fig. 19 *only* as *A. costatus nudus*; but this is a different form from that of the Jura. . . .

"Your specimen is exactly identifiable with specimens which are not uncommon in the marlstone of Dumbleton (Alderton Hill) near here [Cheltenham], and at South Petherton—specimens which for want of a better name I have called *Paltopleuroceras nudum*; these specimens are characteristic of Middle Lias (Marlstone), and of the Spinati η. That is therefore the date of your *N. robustus*. . . .

"Quenstedt called his species *nudus* as being without *spines*. Yours has, I think, some indication of spines. I have a specimen very like yours from Mid: Lias, Tilly sur Seuilles, Calvados, and it is well-spined. Both spined and unspined forms occur at Dumbleton, etc., so this point makes no difference as regards horizon."

The present writer fully concurs with Mr. Buckman's determination of the fossil, and therefore regards the type-specimen of *Nautilus robustus* as of Middle Liassic age.

When the original description of the species was framed it was not possible to give the position of the siphuncle. Fortunately the smaller of the Cheltenham College specimens (the example from Gretton) enables us to supply this deficiency. A portion of the last whorl can be detached and the siphuncle seen very clearly. Where the height of the whorl is 49 mm., its width 56 mm., and the

distance of the periphery from the preceding whorl 42 mm., the centre of the siphuncle is 13·5 mm. from the preceding whorl, and therefore 28·5 mm. from the periphery. The position of the siphuncle may therefore be described as infra-median, or, in the terminology suggested by Professor Hyatt,[1] 'intracentrodorsan.'

The other French specimen originally referred to this species, viz., the example in the British Museum bearing the register number 37,005, also belonged to the Tesson Collection, and bears an original label with the following inscription: "[*Naut*]*ilus inornatus*, d'Orbigny. [Lias] sup[ér]ieur. Curcy." It has the following measurements: diameter (without test near aperture), 166 mm.; thickness (without test on one side), 116 mm.; width of umbilicus (with test), 25 mm. These dimensions agree very closely with those of the type-specimen, the latter having the following dimensions at a diameter of 160 mm.: diameter (with test), 160 mm.; thickness, estimated at about 117 mm.;[2] width of umbilicus (with test), 26 mm. Only a small portion of the body-chamber is preserved. So far, then, as external characters are concerned, it does not seem possible to separate this example from the type-specimen of *N. robustus*. It is true that the example from Curcy is labelled "Lias supérieur," but since the Middle Lias, including beds corresponding to our Marlstone, also occurs at the same locality,[3] it is quite possible that the specimen may have come from these beds.

Of the examples belonging to the Cheltenham College Museum that we refer to this species, the larger one is stated to be from the "Marlstone. Loc: unknown; but probably near Cheltenham, and possibly Alderton Hill." The measurements are: diameter of shell (without test), 220 mm.; thickness (without test), 153 mm.; and width of umbilicus[4] (without test), about 33 mm.; from which it will be seen that this example is not only somewhat larger than the type-specimen, but it is also relatively somewhat thicker, whilst the umbilicus is relatively somewhat narrower. The smaller specimen is labelled "Marlstone, Gretton," [near Dumbleton]. It has the following dimensions: diameter (without test), 165 mm.; thickness (without test), 119 mm.; and width of umbilicus (with test on one side), 26 mm. Only a small portion of the body-chamber is preserved. These dimensions agree fairly well with those of the type-specimen at a diameter of 160 mm. Also the general characters of these fossils agree so well with those of the type, that it will probably be correct to regard the slight differences in their dimensions as merely individual variations.

It may be useful to give in tabular form the measurements of the

[1] A. Hyatt, "Phylogeny of an acquired characteristic": Proc. Amer. Philos. Soc., vol. xxxii, no. 143 (August, 1894), p. 430.

[2] One side of the fossil is broken away, so that the thickness can only be estimated.

[3] "Le type normal du Toarcien de Normandie se trouve aux environs d'Évrecy, de la Caine et de Curcy, où la zone à *Am. spinatus* supporte une argile dite à *Leptæna*, c'est-à-dire à petits brachiopodes d'aspect paléozoique, *Koninckella*, *Cadomella*, etc." (Lapparent, Traité de Géologie, 4me ed., 1900, tom. 2, p. 1089.)

[4] The umbilicus is filled with matrix.

examples which are referred to this species. I is the type-specimen from [the Middle Lias] Les Moutiers, Normandy [B.M. no. 37,010]; II, the specimen from the [Middle] Lias, Curcy [B.M. no. 37,005]; III, the example from the Marlstone, Alderton Hill? [Cheltenham College Museum, no. 900]; IV, the specimen from the Marlstone, Gretton [Cheltenham College Museum, no. 901]. (For comparison with the other examples the measurements of the French specimens are given both at their greatest diameter and also at a diameter of 160 mm. and of 128 mm. respectively.)

	I.				II.				III.		IV.	
	mm.	Ratio to diam.	mm.	Ratio to diam.	mm.	Ratio to diam.	mm.	Ratio to diam.	mm.	Ratio to diam.	mm.	Ratio to diam.
Diameter	204	+ (100)	160	(100)	166	+ (100)	128	(100)	220	+ (100)	165	+ (100)
Thickness	136	+ (66·6)	117	+ (73·1)	116	+ (69·8)	87	+ (68)	153	+ (69·5)	119	+ (72·1)
Width of umbilicus	33	(16·1)	26	(16·2)	25	(15)	20	(15·6)	33	− (15)	26	− (15·7)

I think it highly probable that to this species belongs also a specimen in the National Collection [No. C. 4,487] from the Middle Lias of South Petherton, Somerset. It is entirely septate, and has the following dimensions: diameter of shell (wanting test near aperture), 130 mm.; thickness of outer whorl (wanting test on one side), 78 mm.; width of umbilicus (test present on each side), 21 mm.

III.—On the Distribution of the *Glossopteris* Flora.

By E. A. Newell Arber, M.A., F.G.S., Trinity College, Cambridge; University Demonstrator in Palæobotany.

Among extra-European fossil floras, none is perhaps better known than that of the Permo-Carboniferous rocks of the Southern Hemisphere. These rocks are extensively developed in Southern India, Australia, South Africa, and South America,[1] and there can be little doubt that these regions once formed part of a great continent, to which the name Gondwana-land has been appropriately applied.

The flora of Gondwana-land differs in a remarkable degree from the contemporaneous flora of Europe and North America. The characteristic and predominant plant types in Europe in the Permo-Carboniferous period were *Calamites* among Equisetales, *Lepidodendron* and *Sigillaria* among Lycopodiales, with numerous representatives of the Filicales, and of three groups, now long extinct, the synthetic types Cycadofilices and Cordaitales,[2] and the isolated phylum Sphenophyllales. These compose what we may term the northern type of Permo-Carboniferous flora.

The *Glossopteris*, or southern Permo-Carboniferous flora, consists essentially of four types, *Phyllotheca* and *Schizoneura* among Equisetales, the fern-like plant *Glossopteris*, including *Gangamopteris*,[3]

[1] Seward: Science Progress, 1897, vol. vii, p. 198.
[2] Scott: Trans. R. Soc. Edinb., 1902, vol. xi, pt. 2, p. 331.
[3] Etheridge: Proc. Linn. Soc. N.S. Wales, 1894, ser. II, vol. ix, p. 228.

and representatives of a genus, of at present unknown affinities, but probably belonging to the Cordaitales, *Noeggerathiopsis*.

In India, all these four types occur in the Panchet and Damuda series of the Lower Gondwanas.[1] In Australia, *Glossopteris* and *Phyllotheca* are abundant in the Newcastle series of New South Wales, and in other localities and horizons.[2] *Phyllotheca* was first described by Brongniart[3] from Australian specimens. *Noeggerathiopsis* also occurs in Australia, but *Schizoneura*, although recorded,[4] is apparently rare.

In South Africa, three of these types are found,[5] and stems agreeing very closely with the Indian *Schizoneura* have been recognized.[6] It may be also pointed out that a fossil, discovered by Bain in the Roggeval (Fish River), South Africa, and described and figured by Sir Joseph Hooker[7] in 1852, has some of the characteristics of a *Schizoneura*. This specimen is preserved in the museum of the Geological Society of London, where I have recently examined it. It shows two whorls of linear-lanceolate leaves united into a cup or sheath at the base. The two whorls, however, are quite separate, and on opposite sides of the rock-specimen; whereas in Hooker's figure, which is largely a restoration, they are represented as if in continuity and alternate. The free segments are of unequal length and breadth, and each is traversed by a few parallel and distant nerves. Two of the leaves apparently show some signs of splitting towards the apex. The stem characters are unfortunately not shown, and it is therefore not possible to definitely refer the African specimens to the genus *Schizoneura*, as the evidence of the leaves alone somewhat suggests.

In South America, all the chief members of the *Glossopteris* flora have been recorded in recent years,[8] with the possible exception of *Schizoneura*.

The floras of the various regions of Gondwana-land are therefore all of the same type. Recent researches have also shown that many cases of specific identity occur among the fossil plants of these widely separated areas. *Glossopteris Browniana*, Brngt., is found in India, Australia, and South Africa,[9] *Glossopteris* (*Gangamopteris*) *cyclopteroides*, Feist., and *Noeggerathiopsis Hislopi* (Bunb.), in India, South Africa, and South America, and possibly also in Tasmania. A close identity exists also between other members of the *Glossopteris* flora, as is shown by the occurrence of *Neuropteridium*

[1] Feistmantel: Foss. Flora Gondwana System, 1881, vol. iii: Pal. Indica.

[2] Feistmantel: Mem. Geol. Surv. N.S. Wales, 1890, Pal. No. 3. David: Proc. Linn. Soc. N.S. Wales, 1894, ser. II, vol. ix, p. 249.

[3] Brongniart: Prodrome Hist. végét. foss., 1828, pp. 151 and 175.

[4] Etheridge: Rec. Geol. Surv. N.S. Wales, 1893.

[5] Zeiller: Bull. Soc. géol. France, 1896, ser. III, vol. xxiv.

[6] Seward: Q.J.G.S., 1897, vol. liii, p. 324.

[7] Hooker: Trans. Geol. Soc., ser. II, vol. vii (pub. 1856), p. 227, pl. xxvii, fig. 1.

[8] Szajnocha: Sitz. k. Acad. Wiss. Wien, 1888, Bd. cxvii, p. 219. Kurtz: Revista del Museo de la Plata, 1894, vol. vi, p. 123; 1899, vol. x, p. 43; GEOL. MAG., 1896, p. 446. Bodenbender: Zeit. Deut. Geol. Ges., 1896, Bd. xlviii, p. 743.

[9] Zeiller: Bull. Soc. géol. France, 1896, ser. III, vol. xxiv, p. 349. Seward: Q.J.G.S., 1897, vol. liii, p. 315.

validum, Feist., in India and South America, and *Sphenopteris polymorpha*, Feist., in India and Australia.[1]

For many years the *Glossopteris* flora was regarded both as confined to Gondwana-land, and as entirely distinct in type from that of northern latitudes. It has, however, become more and more clear that neither of these assumptions is correct. *Phyllotheca deliquescens* (Göpp.), of the Permian of Russia, also occurs in Australia, where it was first described by McCoy in 1847, under the name of *P. Hookeri*.[2] In 1898 Amalitsky[3] recorded *Glossopteris* itself from the Upper Permian of Russia, and more recently the *Noeggerathiopsis Göpperti* (Schm.) of Russia was shown to be identical with an Australian fossil plant.[4] These facts would seem to point to the conclusion that a migration into Europe of the southern type of flora took place towards the close of the Permo-Carboniferous period; a theory which is supported by the occurrence of a *Schizoneura* of very similar characters to the Indian form[5] in the Bunter of the Vosges, and of *Phyllotheca* in the Lower Oolites of Italy. In fact, all the four main types of the flora of Gondwana-land are known to have been present in Europe in either Permian or Lower Mesozoic times.

But perhaps the most interesting result arising from recent researches is the fact that the Permo-Carboniferous flora of the Southern Hemisphere can no longer be regarded as entirely distinct in type from that of Europe and North America. This flora is now known to have been composed of a mixture of both southern and northern types in at least two of the four great districts composing Gondwana-land. Such association has been completely demonstrated in South America,[6] and South Africa,[7] and there is reason to believe that it is not altogether wanting in Southern India.[8] We may therefore conclude that land connections existed in Permo-Carboniferous times between the northern and southern continents. In Africa, we can clearly trace such connections, for Potonié[9] has shown that *Glossopteris* occurs in German and Portuguese East Africa, and Zeiller[10] has described typical European Coal-measure species from the Tété Coal Basin of the Zambesi region. Further south still, in the neighbourhood of Johannesburg, an association of both these types occurs.[11]

It is a point worthy of special attention that Australia, so far, remains an exception, in that no trace of any such association of typical members of the *Glossopteris* flora with northern types

[1] Arber: Q.J.G.S., 1902, vol. lviii, p. 12.
[2] Arber: ibid., p. 17.
[3] Amalitsky: Trav. Soc. nat. St. Pétersbourg, 1898, vol. xxviii. Zeiller: Bull. Soc. Bot. Fr., 1899, vol. xlv, p. 392.
[4] Arber: ibid., p. 17.
[5] Seward: Fossil Plants, vol. i, p. 293.
[6] Zeiller: Bull. Soc. géol. France, 1895, ser. III, vol. xxiii, p. 601.
[7] Seward: Q.J.G.S., 1897, vol. liii, p. 315.
[8] Arber: Geol. Mag., 1901, Dec. IV, Vol. VIII, p. 546.
[9] Potonié: Sitz. Gesell. naturf. Freunde, Berlin, 1899, p. 27.
[10] Zeiller: Ann. Mines (8), Mém., 1883, vol. iv, p. 594.
[11] Seward: ibid.

has ever been demonstrated in the Permo-Carboniferous rocks of that continent. Northern types have, however, long been known to occur in Australia in Pre-Carboniferous times.[1] The remarkable absence of such association has recently been called into question. In discussing a paper on some Australian plants, which I laid before the Geological Society recently, Professor Boyd Dawkins[2] stated that he had himself observed the association of *Glossopteris* and *Lepidodendron* in New South Wales. On inquiry, I found that Professor Boyd Dawkins had no specimens to bring forward in support of his assertion, but he kindly gave me particulars of the locality in which he stated such association occurred, with full liberty to make use of the information. The horizon in question was the kerosene shale beds about six miles from Hartley, on the railway between that place and Lithgow, and to the west of Wallerawang. Inquiry was kindly made into this matter for me by Mr. Dun, of the Geological Survey of New South Wales. He writes that such an association is at present quite unknown in this or other districts of Australia. The Geological Survey have just completed the survey of the Lithgow-Wallerawang district, and have collected many hundreds of plant-remains from these rocks, without a trace of a *Lepidodendron* or other northern type. Neither the Survey, nor the Australian (Sydney) Museum collections, contain any specimens showing such an association of northern and southern forms, as Professor Dawkins stated occurred in the rocks of New South Wales.

The remarkable absence of northern types from the Permo-Carboniferous rocks of Australia, and especially the absence of representatives of the group Lycopodiales, would tend to show that Australia was at that time far removed from land connections with the northern continent. It is possible that an association of *Glossopteris* and some Lycopod, such as *Lepidodendron* or *Sigillaria*, may eventually be discovered in that continent, but for the present there is no evidence that any such association occurs there.

IV.—The Pyrenees at the last Geological Congress.

By P. W. Stuart-Menteath, A.R.S.M.

In recently completing, in the valley of St. Girons, and with the cordial assistance of M. Caralp, a pedestrian exploration of the Pyrenees, of which the first results appeared in the *Bull. Soc. Ramond* of 1866, it occurred to me that my view of the recently published *Compte Rendu* and the *Livret Guide* of the Geological Congress might be useful to foreign geologists.

Two Pyrenean excursions are described. That conducted by M. Lacroix is an example of the application of microscopic study in Paris to the confirmation of the observations of the colleagues of their author. He admits, in the recently published *Compte Rendu*, that these results are mistaken in regard to the age of both granite

[1] Carruthers: Q.J.G.S., 1872.
[2] Arber: Q.J.G.S., 1902, vol. lviii, p. 27 (discussion).

and ophite, and that his supposed proofs of the Jurassic age of the latter are the illusions which Pyrenean geologists have long maintained them to be. The traditions of Pyrenean exploration since 1819, which are more important than any published work that M. Lacroix has utilized, have as usual ended by removing the illusion of first impressions in his case.

M. Carez, who conducted the excursion of more strictly geological interest, similarly admits the contrary of what he has previously maintained during many years, but unfortunately he had not time to apply his conversion to the details of the extensive ground with which he deals. A confused and contradictory impression was hence inevitable regarding the most accessible, most typical, and best exposed mountain chain in Europe. Had Pyrenean geologists taken any part in the work of the Congress, this confusion would have been removed by the pointing out of decisive facts which have been ignored in attempts to controvert their results and to supersede their traditions. Practice, as opposed to theory, would have been confirmed in a fashion detrimental to the present attempt in Paris to substitute the theories of Suess for those of Elie de Beaumont and D'Orbigny, which during thirty years enabled Parisian geologists to dictate the results admissible from every local observer. The earlier theories perished through the death of their influential supporters, and because their mathematically definite outlines placed them in sharp opposition to observed facts. The latter disadvantage has been obviated in the more ingenious conceptions of theorists who are usually successful in avoiding any appeal to decisive facts.

The detailed map and sections presented by M. Carez in the *Livret Guide* are slightly modified reproductions of the work of Pyrenean geologists, selected at those points which have been most completely described and figured by them in print; but these documents were produced many years ago, and are not completed by even the additional facts of observation which were known to their authors in 1866, when I commenced the natural development of their work with their assistance and co-operation. Thus, at Salies du Salat the detailed map presented is arranged to produce the belief that no granite exists in the Cretaceous and that the salt deposits belong to the Trias formation, in accordance with theories which M. Carez has opposed to nearly all the authors of serious mapping in the Pyrenees. Yet for many years past I have several outcrops of granite marked on my working maps, and these have been described by Leymerie, Garrigou, Bleicher, and Pouech. Immediately in front of the bridge by which the excursion left the town of Salies the granite is visible to right and left for over 200 metres between Bout du Pont and the Salt Factory; and to the east, between Betchat and Jourdin, it forms bosses of 50 metres in diameter, well exposed on the left bank of the Lens stream. If any foreign geologist will visit these points he will understand the character of the assertions by which M. Carez has nullified the work of all Pyrenean geologists during the last twenty years. M. Roussel has recently admitted the presence of the intrusive

granite as penetrating the Cretaceous; but he has confused the question by assuming that the red marble produced here by alteration of the Cenomanien limestone is Devonian, being unacquainted with the numerous points at which exactly similar marble is produced in the former formation with characteristic fossils in the Western Pyrenees. Two recent surveys at Salies have proved to me the identity of the ground with that of Capvern. As regards the supposed Trias, its introduction by M. Carez is equally theoretical. The fault he figures is impossible, and, in accordance with every engineer acquainted with the plans and borings of similar salt deposits throughout the Pyrenees, I regard the salt as Tertiary and connected with the ophites. It occupies a crater of explosion, excavated to more than 1,000 feet deep across all the rocks of the district older than the Oligocene, and has been deposited in that crater at about the same time as the more lagunar Oligocene salt of the entire Spanish slope of the Pyrenees. The red marls are everywhere an accompaniment of the ophite at its junction with any formation which it happens to traverse. The map of M. Carez ignores the fact that extensive volcanic breccias extend across his supposed fault, and are a common characteristic of the entire sub-Pyrenean plateau, of which the environs of Salies are merely a normal specimen. He supposes here an island, in which peculiarly destructible variegated marls could have resisted the destructive action of the Cretaceous sea, while at the Pic de Bugarach he refuses to recognize such an island in a mass of peculiarly tough dolomite. Yet no such islands can be recognized in the neighbourhood of Salies, while they are admitted to exist at three miles from the Pic de Bugarach. The most striking analogies, as well as every detail of the ground, are ignored in the theory presented to the Congress. The progress of Pyrenean geology has been hampered at every point by similar attempts to discredit all local research by the hasty reproduction of its incompletely published results.

The prolongation of the rocks of Salies is presented by M. Carez at Capvern, where the concealing diluvial sheet of the Lannemezan is removed from the underlying rock plateau. Here he admits the presence of granite, because the main road between the two thermal establishments is cut through its ramifying veins. But he assumes that the rocks which these veins cut must be Triassic, and states that the granite "seems ante-triassic." Off the high road I have found a granite vein of less than four feet in thickness, and exposed along about a hundred yards, at 700 metres north-west of the castle of Mauvezin, cutting vertically through the entire Flysch, which with characteristic composition, structure, and fucoids, forms the whole district, resting on the Cenomanien limestone, precisely as at Salies and in the entire sub-Pyrenean plateau. No practical geologist visiting Capvern, with these indications, can fail to recognize the volcanic breccias intercalated in the Flysch, which attest the Cretaceous age of the intrusions.

A few miles to the south-west, at Ossun, Adé, Julos, etc., M. Carez now admits that both granite and ophite penetrate the same Cretaceous

rocks, while M. Lacroix admits the same in the *Compte Rendu* of the Congress. In the *Bulletin Soc. Geol.* of 1896 M. Carez published elaborate maps and sections representing the said Cretaceous as Cambrian and Silurian, in explicit contradiction of all previous work on the subject. As at Capvern, his sole reason was the theory that granite cannot penetrate the Cretaceous. To my objection that the slates of Lourdes, thus figured as Silurian, contain abundant *Ammonites Deshayesi* and *three closely allied* species which commonly accompany that Ammonite, he replied by assuming inexcusable blunders of surveying, and by stating in the name of M. Douvillé that my determination of the *A. Deshayesi* was a palæontological blunder (Bull. Soc. Geol., 1897, p. 463). In the *Livret Guide* he states that the *Ammonites Deshayesi* was determined by M. Douvillé, while "other authors" quoted "a whole series of distinct species." He unfortunately only recognized this Ammonite in a single quarry where I had thrown aside about two hundred specimens, amongst which I had found the three species or varieties which enabled me to confirm my determination of the *Ammonites Deshayesi*, in spite of its close resemblance to unnamed species of the Lias slates of La Spezia. It is unfortunate that the interests of M. Carez should completely mislead the Congress regarding everything concerned in a case strictly analogous to that of Capvern, where he again repeats his method of reforming the facts of observation.

Together with the representation of the Aptien as Middle Silurian and the Flysch as Cambrian, M. Carez presented in 1896 a reproduction of the panoramic view of M. Jacquot, represented as a section of the Biarritz coast. As at Capvern, he assumes the rocks beside the ophite to be Lias. I have repeatedly proved, by both maps and fossils, that these rocks are the base of the Eocene, normally overlying the Danien along at least 150 kilometres. My observations were confirmed in great detail by the Staff Officer in charge of the topographical mapping of the district, in *Bull. Soc. Geol.* of 1893, and the points left obscure by him have since been completed. M. Carez ignores the whole of this work. He represents quartz crystals in the Eocene as dipyre of the Lias, and reproduces a fault which Jacquot logically assumed in the belief that the coast between Fontarabia and St. Sebastian is a reappearance of the Cretaceous outside the Danien. I proved this coast ridge to be Eocene by a map in the *Comptes Rendus Ac. Sc.* in 1894, and by Nummulites described in *Bull. Soc. Geol.* of the same year. It is unfortunate that M. Carez does not understand the ordinary proof of a fault, but always introduces faults as imaginary lines which, if traced on a map, justify his reproducing that map as an original production by the author of the fault. His arrangement of the rocks at Biarritz has naturally led to one of those monstrous paradoxes of stratigraphy which have become a speciality in the hands of M. Marcel Bertrand. I will only here remark that M. Bergeron figures *beneath* the Danien the same supposed Trias which M. Carez figures as above it, and whose position *above* the Danien is explained elaborately by MM. Bertrand and Michel-Levy. Numerous borings, to which

I have attended for many years, and the accurate plans which they have involved, prove the normal succession which I have already mentioned as prevailing along 150 kilometres right and left of the shifting sands that frequently obscure the Biarritz coast.

Here I must pass on to the remaining sections presented to the Congress. In these, the best work of Pyrenean geologists has been altered by the method of M. Carez so as to confirm the paradoxes of M. Marcel Bertrand. Until his recent treatment of the Biarritz coast these sections of the Pic de Bugarach were the only example in the Pyrenees of that stratigraphy which M. Bertrand has described as typical in mountain chains. As published in the *Bulletin des Services* of 1889 M. Carez' sections appeared conclusive. In January, 1901, my account of a careful examination of the ground was suppressed by the *Société Géologique*; but a brief summary was rescued and read by M. de Lapparent in November, 1900, and is printed at p. 837 of the Bulletin of that year. Since then M. Carez has admitted in the *Bulletin des Services* of May, 1901, p. 65, that his chief proofs of abnormal carting of Urgonian limestone over Senonian marls are mere blunders of surveying. He had here, as in other cases, drawn sections along the strike of the rocks, and arbitrarily assumed that outcrops of intercalated Hippurite limestone were superposed blocks of Urgonian. It is the habitual employment of such methods of proving the paradoxes in question, that renders all criticism of them obnoxious and enables it to be suppressed as polemical. Worse examples could be cited in abundance, but would inevitably be useless where verification on the ground can be evaded. Under the guidance of the Congress by M. Carez, the proofs which he has since repudiated must have appeared conclusive, although the only proof which he now maintains would have appeared obviously inconclusive. The section in the *Livret Guide* represents the ridge north of Bugarach as faulted and broken, although it is a completely visible normal anticline, as correctly figured by M. Roussel. The latter observer, having studied the ground in great detail, has at all points refuted M. Carez. But it is enough to say that the Pic de Bugarach is a Palæozoic island rising out of a mantle of Upper Cretaceous deposited around it. This is proved by the fact that a similar island, admitted to be such by M. Carez, rises out of the same mantle at three miles to the north, while other islands, which M. Carez formerly misinterpreted and has been induced to admit, similarly protrude to the south and west. The relations between these islands and their mantle are precisely analogous to those of the Pic he still refuses to comprehend. The only pretext for any supposed difference lies in the absence of fossils in the Pic de Bugarach, and in the presence of some encrusting patches of Cretaceous on its surface. The section of the Pic presented to the Congress is purely ideal, it does not even attempt accuracy as regards the outward outline, its representation of the Cenomanien is in defiance of its visible arrangement, and the mere notion that such sections can decide points of extreme delicacy in stratigraphy is an outrage on practical geology which M. Carez

has repeated throughout his entire work in the Pyrenees. It is remarkable that such work has been habitually selected as confirmation of the paradoxes of M. Marcel Bertrand, and has been habitually opposed to sections of extreme accuracy on a true scale. The work of Suess is in great part founded on generalizations derived from compilations of such sections, and his latest volume is unfortunately concerned with regions where such data cannot be verified and controlled in the manner which I have found possible elsewhere. In the *Mining Journal* of November 30, 1901, I have given my latest results of such verification; and such work, however obnoxious to theorists, seems to me incumbent on practical geologists who realize the importance of their science as a basis of industrial operations rather than as a source of confirmation in questions of controversial theology.

As regards the excursion from Lourdes to Gavarnie, I may remark that in 1865 M. Carez obtained from me a map of the Western Pyrenees, from the ocean to the valley of Lourdes, which appeared in the compiled map of France of Carez and Vasseur. In the *Bull. Soc. Geol.*, 1887, p. 185, I protested against the arbitrary introduction of a mass of Silurian as overlying the Carboniferous. The Survey geologists subsequently confirmed in detail the structure of the district in question as I had described it, and hence the quotation of a gigantic stratigraphical paradox was prevented in this instance, although M. Carez professed inability to understand the meaning of my protest. Similarly, the official geological map of the Pyrenees, published in 1890, represented as Cambrian the vast band of Upper Cretaceous which I figured for the map of Carez and Vasseur between Cauterets and the Pic D'Orhy. This contradiction, vigorously sustained against me by M. Marcel Bertrand in November, 1887, would have furnished gigantic examples of the *charriages* to which the latter writer attributes mountain structure; but as his reply consisted solely in insinuations of ignorance, and as I have since repeatedly proved his Cambrian to be Upper Cretaceous by admitted fossils at decisive points, it has now been admitted by the Survey geologists to be what I represented it. Since then I have made known two other bands of Secondary rocks in the Palæozoic of the official map, one north of Gavarnie and one running east and west of Argeles. Each of these is being now vaguely described without fresh proof, so I may here state that I have found five Hippurites in the band of Argeles at 1,200 metres north-west of Arcisans-Dessus, while in the band north of Gavarnie I have found the same Lias corals which characterize the base of the Argeles band at the Col d'Espandels and many other points. The Congress might thus have remarked that the Pyrenees resemble the Alps in presenting interior synclinal bands of Secondary rocks from the Trias to the Flysch, although this fact is deliberately contradicted by the official geological map of 1890, whose errors are reproduced in that of Europe which confirms the theories of M. Bertrand. It is an instructive fact that the attempts to introduce the *charriage* theory in these cases, as at the Pic de Bugarach, are

preventing the publication of the details which the most experienced geologists of the Pyrenees have been long accumulating regarding the real structure of the most typical and best exposed mountain chain in Europe. Before even the most salient facts of that chain have been permitted to appear in the ordinary and essential channels of geological documentation, a theory of mountain structure derived from the elaborate compilation of Suess has been made the criterion of fact and based upon the selected errors of writers who have obtained, on various pretexts, portions of the work of practical geologists in the Pyrenees. The entire opportunity of verification afforded by the Congress has been subordinated to the interests concerned. International co-operation in such matters may only tend to confirm attempts to override observation, and to silence those who have acquired the long preliminary practice required to correct the illusory and perspective impressions of mountain structure. Parisian geologists apparently fail to realize the inconvenience of vast innovations in maps whose freedom from theoretic conjecture has frequently cost the sacrifices of a lifetime.

In the superficial geology of the Gavarnie valley the Congress was equally misled. In 1866 I proved, in the *Bulletin Société Ramond*, that the conglomerate of the Park of Pau, previously described by Charles Martins and others as a moraine of the Glacial Period, was situated at sixteen kilometres *outside* of the extreme limit of the moraines of that period, and that it represented the Oligocene ice of the Superga of Turin, with which I was familiar. Charles Martins hastened to correct his conclusions; but, assuming the opposite extreme in a theoretical map of the glacier of Gavarnie, placed the upper limit of that glacier at fully 1,000 feet below the distinct lateral moraines which can be seen to the north of Argeles by any observer who will climb the mountains. In the *Bull. Soc. Geol.*, 1868, p. 697, I figured a great fault at Gavarnie, which had been overlooked by Dufrénoy. This was adopted by Magnan, and generalized into a system which has long misled observation. At Gavarnie that fault juxtaposes a character of erosion which is common on the Spanish side, in abrupt contrast with the very different character which prevails in the French Pyrenees. The Gavarnie valley, in receding rapidly through the greater erosion on the moist and snowy French slope, has abruptly entered the Cretaceous and Tertiary sheet of the Spanish side. The same circumstance accounts for the peculiar scenery of other Pyrenean valleys, but at Gavarnie it is accentuated by the prominence of the fault and the considerable drainage of the lofty Mont Perdu. It is unfortunate that personal questions should prevent, at every point, the clear recognition of the facts of Pyrenean geology, owing to the manner in which their history has been altered in Paris in defiance of both documents and dates. The briefest statement of observations might have removed difficulties that have hampered progress for thirty years, had such statement not been rendered obnoxious by previous misrepresentations which it is impolite to notice and unpleasant to explain. In welcome confirmation of

certain theories in vogue, a complete geology of the Pyrenees has been developed, to which no Pyrenean geologist can contribute without abandoning those habits of cautious statement which are essential to the integrity of his work.

Note.—Since the above was posted, in January last, the points described have been largely discussed in Parisian publications. It is admitted that the granite, ophite, and supposed Trias are above and not beneath the Cretaceous. It is hence assumed that they *must be* abnormally carted caps of those ancient formations. The entire evidence of their age being admittedly false, that age is maintained by a paradox that contradicts every detail of the district. There could be no shadow of doubt that they are beneath the Cenomanien, were it not that they are frankly eruptive, and at Salies, as at a hundred other points, flanked by lentiles of eruptive breccia intercalated in the Cretaceous Flysch. In the Alps, the abnormal carting of the Brèche du Chablais is similarly assumed, to save the assumption that its volcanic vents are Triassic by micrographic theory. M. Marcel Bertrand regarding the Alps, and M. Haug regarding the Pyrenees, have propounded theories before visiting either chain. Since first exploring the rocks of Salies with the assistance of Leymerie in 1866, I have endeavoured to sacrifice all theory to observation. Unless practical geologists cease to despise controversy, they will find, like myself, that any mention of their work is an outrage, and that any field survey is intolerable polemics. The entire geology of Asia having been yesterday reformed from Vienna, similar treatment of Alps and Pyrenees is inevitable. It is easier to silence all local observation than to repeat its task.

V.—Contributions to South African Petrography.

By F. P. Mennell, F.G.S., Curator of the Rhodesia Museum, Bulawayo.

It is remarkable, considering the enormous development of igneous rocks in South Africa, that so little has been written concerning the features they present in the field or under the microscope. Right away from Cape Town into the tropics, plutonic masses, dykes, and lava-flows interrupt the continuity of the sedimentary deposits with astonishing frequency. Some of these rocks, like the Cape Town granite and dolerite, are probably of pre-Silurian age;[1] others, like the Kimberley lavas, were erupted during the Secondary period; while others, again, like the dykes and lavas of the Zambesi Valley, are probably of late Tertiary or even geologically recent date, as evidenced by the numerous geysers and hot springs[2] which represent the final phase of not long antecedent volcanic activity. They appear to bear the same relation to the volcanoes of Central Africa as the British Tertiary lavas do to those of Iceland.

[1] They are overlain unconformably by a thick formation which is itself older than the earliest fossiliferous beds (Devonian) of South Africa.

[2] See Ferguson on the geysers of the Zambesi and Kafui Valleys, Proc. Rhodesia Sci. Assoc., 1902.

In the present chaotic state of petrological nomenclature it is necessary to explain the significance of the terms employed in describing the rocks. No system of classification can be regarded as wholly satisfactory, but it certainly seems hopeless to rely on such features as the presence or absence of particular minerals. Such a course brings together types which differ widely in chemical composition, and separates others which are chemically and genetically closely related. In the brief notes which follow, the grouping depends solely on mode of occurrence and chemical composition, a method of classification which appears to be steadily gaining ground owing to its simplicity. The significance of the nomenclature, which accords strictly with the classification adopted, will be readily perceived from the following table, names in general use being employed as far as possible and simply endowed with greater precision. In individual cases the name of the most characteristic mineral is prefixed for purposes of distinction.

	Eruptive (= Lava-flows).	Intrusive (= Dyke rocks).	Plutonic (= Rock consolidated at great depths).
Acid	Rhyolite ...	Granophyre ...	Granite
Sub-acid ...	Trachyte ...	Felsophyre ...	Syenite
Sub-basic ...	Andesite ...	Porphyrite ...	Diorite
Basic	Basalt ...	Dolerite ...	Gabbro

With these preliminaries we may pass on to the rocks themselves. In South Africa as elsewhere, acid lavas and basic plutonic rocks are rare, while basic lavas and acid plutonic masses are developed on an enormous scale. The only rhyolite which has come under my notice occurs near the Express Mine in the Umniati district of Mashonaland. It shows sparingly distributed phenocrysts of hornblende and orthoclase felspar with rarer quartz, set in a glassy groundmass crowded with globulites, margarites, and longulites. Partial devitrification is evidenced by a cloudiness between crossed nicols, but there are no signs of spherulitic structures. Ilmenite and brilliantly polarizing sphene occur as accessories, but neither is abundant.

Sub-acid lavas appear, like the rhyolites, to be poorly represented, and I am not able to refer any rocks to this division with anything like certainty. There are also a number of lavas probably belonging to the andesites, but in the absence of analyses discrimination from the basalts is a matter of considerable difficulty. A 'melaphyre'[1] from the Kimberley Mine at Kimberley belongs, however, to this class. It is a fine-grained aggregate of lath-shaped felspars with some interstitial chlorite, etc., which may partly represent originally vitreous material. Some of the felspar is untwinned, and is probably orthoclase, while the twinned crystals seem to be andesine. There is no porphyritic constituent, and the amygdaloidal cavities, which are lined with chlorite and filled with chalcedony or with calcite, are the most interesting feature of the rock. Another and rather more basic andesite occurs interstratified with sandstone

[1] This is obviously a different rock to that described by Stelzner.

at Taba s'Induna, a conspicuous hill about 12 miles north of Bulawayo. The under part of the flow is highly amygdaloidal, but the scoriaceous upper portion was evidently denuded off before the deposition of the overlying rock. Sections from the compact parts of the mass show it to be made up of lath-shaped felspar with much less abundant granular augite. Glomero-porphyritic aggregates of larger felspars are distributed through the mass, and magnetite occurs as an accessory.

We now come to the basalts, and here our only difficulty is one of selection. Undoubted lava-flows are not particularly common in Cape Colony, but further north, and especially in the Zambesi Valley, they are developed on an extensive scale. A rock from Livingstone Island at the Victoria Falls may be taken as typical. It shows a flow structure which is by no means so clear under the microscope as on a polished surface, but is indicated by the distribution of coarse-grained glomero-porphyritic aggregates of augite and labradorite. The bulk of the rock is a granular mixture of augite, plagioclase, and magnetite, with some interstitial matter, the ophitic structure not being developed in any of the specimens I have examined from this extensive area. Another example from

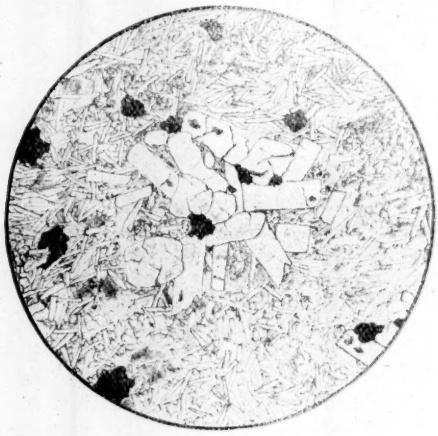


Fig. 1.

the north bank of the river at the Falls is not so fresh, but otherwise quite similar. Some varieties are highly amygdaloidal, the cavities being filled with pectolite and other zeolites as well as calcite, agates, etc. The individual flows can frequently be distinguished by the occurrence of bands of these amygdules at intervals in the great masses of lava. A specimen from the Dekka River on the Falls Road presents some interesting features (Fig. 1). Resinous-looking crystals of felspar are obvious to the naked eye; indeed, they occasionally attain a length of $\frac{1}{2}$ inch, and under the microscope these are seen to form part of glomero-porphyritic aggregates which also comprise good-sized crystals of colourless augite and a few

rounded grains of olivine, this being the only case in which I am able to record olivine from the rocks of the Zambesi Valley. The groundmass is largely of the usual type, a granular aggregate of lath-shaped felspar, augite, and magnetite, but there is also a considerable amount of glassy material, which is either brown in colour and isotropic, or bright orange, with an imperfect spherulitic structure between crossed nicols.

Though by no means the most abundant type, South Africa affords some good examples of olivine basalt. A beautiful one[1] occurs amongst the rocks which surround the volcanic pipes of the Kimberley diamond-mines, from which they were no doubt originally extended. It is holocrystalline, with a well-marked ophitic structure, and I know of no rock in which the distinction between olivine and the pyroxenes is so well indicated. Both augite and enstatite are present, and their cleavages are well developed, pinacoidal ones being shown by both rhombic and monoclinic variety in addition to that parallel to the prism. Twinning is very common, and the felspars penetrate the crystals in all directions. The olivine, on the other hand, shows distinctly higher refraction and stronger double refraction than the pyroxenes, and the absence of cleavage is in striking contrast to its conspicuous development in their case. It occurs in rounded grains and granular aggregates, which are not as a rule penetrated by the felspars, and are traversed by irregular cracks, sometimes rendered more apparent by incipient serpentinization, though in no case has this proceeded far. The felspars give lath-shaped sections showing repeated twinning, and evidently belong to a variety near anorthite, the maximum extinction angle being about 40°. There are also larger allotriomorphic crystals, which are untwinned but are strongly zoned in layers of different composition. Rather large irregular granules of ilmenite are somewhat sparingly distributed, and perofskite also appears to be present as an occasional accessory.

We now come to the consideration of the dyke rocks, which are more evenly distributed among the various types. I have adopted the term granophyre for the acid division, as it is etymologically a highly appropriate term, but not without some misgivings owing to its having unfortunately been restricted by many authors to those rocks in which the groundmass assumes a micrographic structure. Quartz felsite would perhaps be less open to objection in some respects, but any such double-barrelled expression is very cumbrous when a prefix becomes necessary. With this explanation I do not think that my usage of the term need give rise to any misconception.

Some beautiful granophyres, in the ordinary acceptation of the word, occur near Fort Gwelo in Matabeleland. Large phenocrysts of felspars (chiefly plagioclase), and more rarely of corroded quartz, are set in a groundmass which is partly spherulitic and partly 'micrographic.' The former type largely predominates, and the spherulites are frequently seen to be composed of radially disposed

[1] This is no doubt the rock referred to by Professor Bonney, GEOL. MAG., 1897, p. 449.

micrographic intergrowths of quartz and felspar; indeed, under a high power most of them are resolvable into micropegmatite. Large flakes of biotite occasionally occur, and smaller, sometimes idiomorphic, crystals of hornblende are also present. Both ferro-magnesian minerals are somewhat decomposed, chlorite and calcite occurring as alteration products. The felspars are beautifully zoned and for the most part very fresh. They frequently form a nucleus for the spherulites, or the latter may diverge from their angles.

Another type of granophyre occurs in Northern Rhodesia (British Central Africa), near the junction of the Chibwe and Zambesi Rivers. It shows good-sized phenocrysts of felspar, and smaller ones of quartz, set in a purplish groundmass. It bears a considerable resemblance to the well-known 'quartz porphyry' which occurs so abundantly as boulders in the New Red Breccia near Teignmouth in South Devon. The groundmass is, however, of a finely granular type, and is by no means so red. Both quartz and felspar occur in idiomorphic but corroded crystals, and the latter seems almost entirely referable to microcline, though decomposition has obscured the cross-hatching in many cases. Magnetite and sphene are abundant accessories, while there are also occasional prisms of zircon.

At Francistown, in Bechuanaland, occurs a granophyre in which hornblende is the principal porphyritic constituent. A second generation belongs to the groundmass, which is, however, composed principally of quartz and felspar with abundant apatite and sphene. The quartz, though not thoroughly idiomorphic, occurs in grains and granular aggregates, and almost invariably presents convex boundaries to the felspar. Orthoclase predominates, but twinned plagioclase is also present.

A rock which has quite a granitic appearance in hand-specimens occurs at the Dopodge River near Waukie, in Northern Matabeleland. It shows large porphyritic felspars, which are seen under the microscope to be orthoclase. They are frequently twinned on the Carlsbad plan, and often show rounded inclusions of quartz. Plagioclase is also present. Both muscovite and biotite occur, sometimes as aggregates, and the latter is largely chloritized. The groundmass, which does not make up a very large bulk of the rock, is partly micrographic and partly micropegmatitic. In the latter case the quartz is of what has been called the 'vermicular' type, being rounded and showing a wavy outline in longitudinal sections.

The designation felsophyre has been adopted instead of the very ambiguous term felsite for the dyke rocks corresponding to the syenites. A number of the 'amygdaloidal diabases' and 'felsites' of Cape Colony no doubt belong to this division, but without chemical analyses it is difficult to assign them to their proper position. A large intrusion near Belingwe, in Matabeleland, may, however, be referred here with some certainty (Fig. 2). It consists of idiomorphic felspars (orthoclase and oligoclase) imbedded in a 'felsitic' groundmass, stained with chlorite, representing the original ferro-magnesian mineral. The orthoclase is identified by the simultaneous straight extinction of the two halves of a Carlsbad

twin, while the oligoclase gives a maximum extinction angle of about 10°, and is nearly always twinned on the pericline as well as the albite type. The prism faces are well developed, especially in the orthoclase, and the crystals are usually elongated in the direction of the vertical axis. A few grains of ilmenite occur in the groundmass. Another rock from Belingwe may be referred to the porphyrites. It is very similar to the last in appearance and structure, but is obviously more basic. Andesine is the predominant porphyritic felspar, and patches of chlorite appear to represent a ferro-magnesian constituent which was also possibly porphyritic. Numerous granules of leucoxene indicate the presence of original ilmenite, and apatite also occurs in shortish prisms. Epidote and calcite are decomposition products.

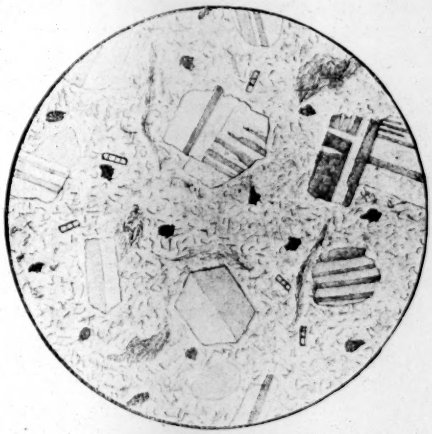


Fig. 2.

Quite another type of porphyrite is represented by a specimen from the Modder River. It consists of an aggregate of fair-sized lath-shaped felspars, with elongated crystals of augite, largely chloritized, granules of ilmenite, small but numerous, and a good deal of glass. The last is of quite a bright green colour and perfectly isotropic, but it encloses numbers of minute colourless spherulites, which never give a black cross in polarized light, but show an extinction curve exactly similar to the 'brushes' of a biaxial interference figure. The felspar seems to be mostly andesine. Like many of the South African dyke rocks this example is amygdaloidal. The amygdules are almost spherical as a rule, and are made up of calcite and quartz, sometimes intermixed, with a border of feebly pleochroic chlorite. Crystals of pyrites occur as inclusions in the calcite.

We now come to the dolerites, which present great diversity of structure. Glassy examples occur at the Criterion Mine not far from Bulawayo and at the Bonsor Mine in the Selukwe district of Matabeleland. At the former locality the intrusion appears to be

completely glassy. It is considerably altered, being practically a 'palagonite,' but the mass of the rock is quite isotropic, though it is crowded with crystallites (longulites) and minute specks of magnetite. It shows occasional rather irregular spherulites. At the Bonsor Mine the glass forms the margin of an intrusion into quartz schist, and becomes rapidly more crystalline and apparently also more basic as it is traced from the contact. About an inch from the edge it is dark brown in colour, and crowded with crystallites and tiny microlites. It shows also idiomorphic phenocrysts of augite and more or less corroded felspar, the latter evidently a basic variety and largely converted into epidote.

The more crystalline varieties are usually of the granular type and do not as a rule contain olivine. The dykes which pierce the Cape Town granite afford good examples. They consist of lath-shaped felspar, augite, rarely idiomorphic, but of prior consolidation to the felspar, magnetite, ilmenite, and a little interstitial matter. Chlorite occurs as a decomposition product of the augite. The felspar appears to be labradorite, and one specimen of the rock gave a silica percentage of 52·41.[1]

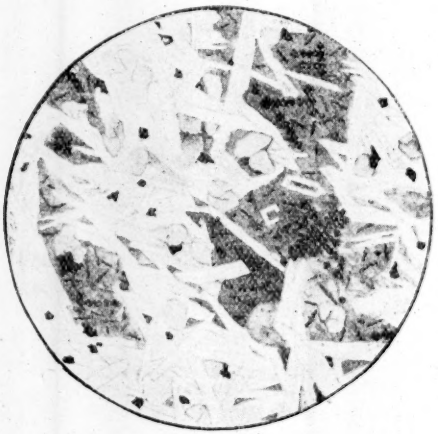


Fig. 3.

A very similar rock, but with a good deal of glassy matter, penetrates the Matopo granite mass near Forest Vale (Fig. 3). The glass is brown in colour and quite isotropic. It is crowded with little rods of magnetite, very long and thin, while skeleton crystals of felspar are also of frequent occurrence. Magnetite is very abundant all through the rock and is almost invariably idiomorphic, little octahedra being common which are frequently grouped in rows, sometimes apparently along the edges of a cube. The lath-shaped felspars often show bifurcated terminations and inclusions of the groundmass. This rock is near the margin of one of the outliers of Tertiary (?)

[1] Cohen: N.J. für Min., 1874. See also Shaw: Proc. S.A. Phil. Soc., vol. i, pt. 2 (1879), p. 59.

sandstone which rest unconformably on the Bulawayo schists and the marginal portions of the Matopo granite mass. These are evidently of the same age as the coal series and associated beds of the Zambesi Valley, from which several lavas have been described. A dyke penetrating the sandstone itself at Mafungaburi Peak, Matabeleland, is of the same type, but contains a smaller proportion of glass, while the crystalline constituents are of larger size. The augite is frequently idiomorphic, and is of prior consolidation to the felspar. Good-sized rods of magnetite are abundant, but do not show the definite outlines of the Forest Vale variety. Another rock from the Zimba River, Northern Rhodesia, is holocrystalline and rather coarser-grained. The felspars frequently show pericline as well as albite lamellation, and must be nearly related to anorthite. The augite occasionally shows crystal outline, and microlites occur as inclusions in the felspar, but the latter sometimes penetrates the larger crystals. Rods of magnetite are freely scattered through the mass, and apatite is also present.

A transition to the ophitic structure is seen in a specimen from the Waterworks, about 4 miles from Bulawayo. It consists of large plates of augite, for the most part in a beautifully fresh condition, and very decomposed felspar. It seems evident that the augite originally tended to be porphyritic, but when the felspar commenced to crystallize out, crystals continued to grow instead of a second generation forming in the groundmass. This is shown by the fact that the felspars never occur as inclusions in the augite, and seldom penetrate more than a very short distance from the margin of the crystals. If there was originally any glassy matter it is now lost in the confused mixture of decomposition products due to the alteration of the felspar. Ilmenite is abundant, and sometimes shows fine examples of skeleton crystals, while a colourless mineral with very strong refraction and double refraction is probably sphene.

A beautifully fresh ophitic olivine dolerite occurs near Fort Gwelo, Matabeleland, on the Sebakwe Road. The felspar gives the usual lath-shaped sections in most cases, and frequently shows pericline lamellation. The augite is penetrated by the felspar in all directions, and often occurs in aggregates. The olivine is rarely penetrated by the felspar, and shows a rougher surface and higher interference tints than the augite. The cleavage is occasionally shown, and the mineral is traversed by the usual irregular cracks, which are now and then rendered more prominent by incipient serpentinization. A curious feature is the enclosure in the olivine of small crystals of a brownish pleochroic hornblende with well-developed cleavage. A few minute flakes of biotite also occur. Both these minerals are usually associated with grains of magnetite.

Among the plutonic rocks the granites afford examples of a number of varieties. The coarse-grained biotite granite of Cape Town has been described by Cohen [1] and others, so that it is needless to enumerate its normal features. One variety, however, seems worthy

[1] N.J. für Mm., 1874.

of mention, a graphic modification with tourmaline as an abundant accessory. The latter mineral seems to be intergrown with the felspar in a similar way to the quartz. It is a yellowish variety without marked pleochroism, and the interference tints are not masked, as is often the case, by the strong absorption. It may possibly be regarded as having replaced quartz, but it seems more likely that the intergrowth is more apparent than real, and is due to the penetration of the mineral into cleavage cracks in the already consolidated felspar. A graphic granite from Northern Rhodesia, about midway between Kalomo and Monze, may also be noticed. The felspar, which builds pink crystals several inches in length, is microcline. The quartz does not occur in well-defined skeleton crystals, but gives a somewhat irregular wavy longitudinal section and a rounded transverse one. Occasional small flakes of muscovite are present.

The great granite mass of the Matopos, which forms the backbone of Southern Matabeleland, presents some interesting features. The normal granite in hand-specimens closely resembles the Dartmoor rock (e.g. that of Hay Tor). In a rather fine-grained example from the Khami Valley the dominant felspar is, however, seen under the microscope to be microcline. It is obviously the last product of crystallization, as it even encloses the small patches of micro-pegmatite which occasionally occur. Orthoclase and oligoclase are also present, the former being apparently the felspar of the micrographic intergrowths. Biotite is the ferro-magnesian constituent. Sphene and apatite are the accessories. Near Bulawayo, which is situated on the contact zone, the rock assumes a very different aspect. The structure is decidedly gneissic, and the felspars are flesh-coloured. The appearance of foliation is probably due to movement before complete consolidation (Fig. 4). This seems to be implied by the granulation of the quartz and microcline[1] and the absence of deformation in the minerals of prior consolidation. It does not do, however, to place too much reliance on this feature, for, as I have previously[2] pointed out, it is precisely these minerals which most readily yield to the effects of pressure, and the quartz may be completely granulitized before the other minerals are appreciably affected. Hornblende is here the dominant ferro-magnesian constituent, though biotite is present in most slices. In the pegmatite veins which ramify through the mass and are obviously of late consolidation, microcline takes the place of the other felspars, but in the normal rock orthoclase seems to be rather more abundant and oligoclase frequently forms large pseudo-porphyritic crystals. Sphene, apatite, and zircon are all fairly abundant, the two former building rather large crystals.

The syenites are represented by what I may term the Hillside intrusion, three miles from Bulawayo, which is of so much interest that I hope to describe it fully in a future paper. I may mention,

[1] See MacMahon on the gneissose-granite of the Himalayas, GEOL. MAG., 1897, pp. 345–355.

[2] "The Copper-bearing Rocks of South Australia": Brit. Assoc., 1901.

however, that the most abundant variety is an even-grained rock of typically granitic structure, but entirely destitute of quartz. The felspar is almost exclusively microcline, while hornblende and augite are about equally abundant. Sphene occurs in very perfect yellowish crystals, while apatite, zircon, and magnetite are also present. An augite-diorite occurs as a basic modification of the mass, but more typical diorites occur as segregations from the Matopo granite near Bulawayo. In these hornblende is the ferro-magnesian constituent, while microcline, oligoclase, and orthoclase are present as in the granite itself. Apatite and sphene are very abundant, and often form large though somewhat irregular crystals. There are also a few granules of magnetite.

Fig. 4.

Numerous intrusions or segregations of gabbro occur in the very interesting plutonic complex round the Umniati River in Mashonaland. One example from the Goedyema Road, north of the Sarui River, is a beautifully fresh rock made up entirely of augite and felspar. The structure is typically granitic and the grain coarse and even. There is not a single grain of magnetite present, and the rock is consequently remarkably light-coloured for so basic a variety. Most of the augite shows diallagic striation and schillerization, due to the presence of two sets of rather large, regularly arranged inclusions. The felspar is evidently near anorthite, giving symmetrical extinctions up to 37°. Specimens from three other localities in the same district have characteristics which seem to be due to the influence of the rocks into which they were intruded. In one from the Sarui River, enstatite is the most abundant ferro-magnesian constituent. It occurs in elongated crystals of considerable size and is partially altered to serpentine. Augite is also common, and often shows good cleavage and a basal striation. This, combined with twinning on the orthopinacoid, gives rise to good examples of the 'herring-bone' structure. Repeated twinning is also well

shown, one large crystal being divided into six equal-sized lamellæ. The felspar is allotriomorphic. It forms large grains which exhibit Carlsbad, albite, and pericline lamellation. The extinction angle rises to at least 30°. Small flakes of biotite and granules of ilmenite are present. A little quartz also occurs, chiefly as micropegmatite. A specimen from the Gwelo-Selukwe Road shows more abundant biotite in small, very pleochroic flakes. The dominant ferro-magnesian mineral is, however, augite, in which the herring-bone structure is almost always shown. A little enstatite and hornblende are present, the latter sometimes bordering the augite. The plagioclase evidently approaches anorthite in composition, and forms larger grains than the other constituents. Ilmenite sometimes builds good-sized irregular granules, while quartz, chiefly in micrographic intergrowth with felspar, is sparingly distributed. A specimen from another locality is remarkable for the abundance of strikingly pleochroic yellowish biotite, so that it may be described as a biotite gabbro. Hornblende is also present and sometimes borders the augite. In other respects the rock is similar to the two previous varieties.

Though somewhat rare, as in other parts of the world, ultrabasic rocks are widely distributed in South Africa. They have, indeed, received more attention from European geologists than any of the other divisions. The breccia and eclogite of Kimberley and of Jagersfontein in the Orange River Colony are so well known that it is needless to do more than mention them. The very interesting melilite-bearing rock from the Spiegel River in Cape Colony, described by Professor Cohen,[1] provides the only instance of the occurrence of a felspathoid, other than nepheline, in our province, though leucite basalts, etc., have been recorded from Kilimanjaro in Central Africa. Picrites have been described from the Transvaal and elsewhere by various writers, so I will confine myself to a brief mention of a rock from Porselt's Vlei on the road from Inciza to Belingwe in Southern Matabeleland. It is very coarse-grained and of a uniform dark-green colour. Olivine appears to be the sole constituent, as iron-ores are conspicuous by their absence, and there are no indications in thin section which would lead one to suspect the presence of any other ferro-magnesian mineral. The rock is beautifully fresh and quite free from even incipient serpentinization.

VI.—River Development.

By S. S. Buckman, F.G.S.

IN the Quarterly Journal of the Geological Society, May, 1902, vol. lviii, p. 207, Mr. A. Strahan has a paper on the "Origin of the River-System of South Wales, and its Connection with that of the Severn and Thames." It is with the part of the paper expressed in the latter portion of the title that I am more particularly concerned; for in that connection Mr. Strahan remarks

[1] T.M.M., 1894, p. 188. See also Ann. Rep. Cape Geol. Comm., 1898.

in a footnote (p. 219), "The theories put forward by Mr. S. S. Buckman in Proc. Cotteswold Nat. Field Club, vol. xiii (1900), p. 175, following the lead of Professor W. M. Davis, appear to me to transgress the limits of legitimate speculation." It seems rather curious that in a paper like this there is no further reference to the work done by Professor Davis, no attempt to consider his views, only a dismissal of them, implied in the rejection of the views which I have advanced in accordance with his teaching, which views, by the way, I gave in more detail in *Natural Science*, April, 1899, vol. xiv.

However, we are bound to infer from the manner of Mr. Strahan's condemnation that his own theories are within the limits of legitimate speculation. Let us see how far they bear investigation.

The author postulates an anticline of the Chalk, with a Caledonian trend, more or less coinciding with the present escarpment in direction. How far to the north-west of the present escarpment it lay he does not indicate; in this matter he is vague. Only he tells us that "The rivers rising in the low-lying [*sic*] Oolite region flow eastward against the general run of the country [*sic*] . . . . and were initiated on an eastward slope of Chalk," etc. Therefore the anticline must have been situated at least as far north-west as the line of the present Oolite escarpment. Evidence he gives in a footnote: "The existence of certain valleys breaching the [Chalk] escarpment, but not now occupied by streams is explained by Prof. Gregory on the supposition that they carried the drainage from that part of the Chalk plain which has perished." Quite so; granted, so far as to say that the breaches were made by rivers flowing off high ground beyond the Chalk escarpment—how much of it was Chalk is unimportant. But the same argument applies, with greater force, to the Cotteswolds. The breaches of the Cotteswold escarpment are even more noticeable than those of the Chalk, and, as I pointed out before I had heard of Professor Davis or his theories, these breaches must have been cut by eastward-flowing rivers,[1] an idea which also had occurred to Dr. T. S. Ellis years ago.[2] These rivers must have drained a large area to collect the necessary volume of stream[3]—that is to say, Mr. Strahan's anticline would have to be placed well to the north-west of the present Oolite escarpment. This is legitimate speculation; because Mr. Strahan can hardly complain if the same argument which is used in regard to the breaches of the Chalk escarpment is applied to those of the Oolites. But it is a *reductio ad absurdum* for Mr. Strahan's contention. The anticline which he wishes to place eastward of the Severn in order to deflect that stream must, following his own line

[1] Q.J.G.S., vol. liii, p. 626.

[2] I have given an account of all this in my above-mentioned paper in *Natural Science*.

[3] The meander curves of the Cotteswold valleys, pointed out to me by Professor Davis, form the strongest evidence here, and I am afraid Mr. Strahan does not appreciate its importance. But any theory of river development must account for these meanders; it cannot ignore such facts. They are illustrated in my two papers above mentioned.

of argument, be placed to the west of the Severn, where it would fail in its object.

Certain remarks of Mr. Strahan now call for notice. He speaks of the "low-lying Oolitic region." But the Oolitic region of the Cotteswolds is from 200 to 300 feet higher than the Chalk of the Chilterns or Berkshire Downs. He speaks of the rivers flowing against the general run of the country. But they do not—they flow with the dip. The general long slope of the country is from the Oolites to the Chalk.

Further, Mr. Strahan says, "The Chalk escarpment now forms the main water-parting through much of its range across England" (p. 219). But in his map he shows the Chalk escarpment extending from the English Channel to the Wash, about 210 miles; and yet he only shows the coincidence of water-parting and escarpment for some 40 miles. These are not matters of speculation, they are matters of fact.

In another matter of fact Mr. Strahan has erred. In his map (pl. v) he has placed the Vale of Moreton in the wrong place, on the edge of the Cotteswold escarpment. But that is a good dozen miles too far to the west. It is very convenient for his theory, but then it is wrong in fact, and wrong facts do not seem to be a satisfactory basis for legitimate speculation. As a matter of fact the Vale of Moreton is on the east of the Cotteswolds, not on the west: it is a good dozen miles to the east of the headwaters of the Thames streams. This is particularly unfortunate for Mr. Strahan's theory. He says that his anticline must have run "along the line of the water-parting. Traces of such an anticline have been detected by Mr. Buckman in the Vale of Moreton." But put the Vale of Moreton in its right place, and these two statements are flatly contradictory. The Vale of Moreton is not along the line of the water-parting, it is to the east of it. And if the anticline of the Vale of Moreton had had any appreciable influence it must have made the Cotteswold streams flow westward, not eastward.

Is it legitimate to quote my evidence of the Vale of Moreton anticline in this connection? I think not. The anticline of which I speak in the paper quoted by Mr. Strahan (Q.J.G.S., 1901, vol. lvii. p. 146) is relatively a very small one, formed in Inferior Oolite times, denuded, and completely covered over again by later Inferior Oolite rocks. No doubt there is the principle "once an anticline, always an anticline": as I have pointed out (p. 147) evidence of successive movements along the same line of weakness may often be seen. I will allow Mr. Strahan to make what he can of this. He is seeking for an anticline with an axis having a Caledonian trend. The Moreton anticline has a Malvernian trend; it is a feeble continuation of the line of the Pennine range. Therefore, the Moreton anticline has not the direction Mr. Strahan requires; and, as I have shown, it is not in the position that he wants, it is not where he has marked it on his map, and it does not coincide with the water-parting.

It seems very remarkable that for an anticline such as Mr. Strahan

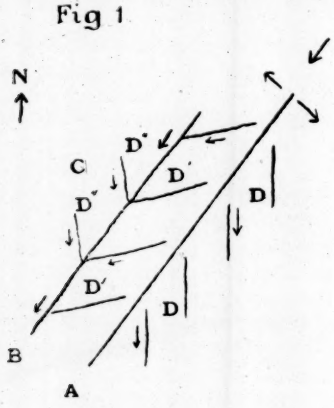
postulates, an anticline so important as to have divided the rivers of England and to have deflected the Severn, there should be no more evidence than "traces." If there were such an anticline as Mr. Strahan supposes there must be more than traces. This Chalk anticline could not have been formed without the upheaval of the underlying Jurassic rocks. Therefore, north-west of the water-parting, that is, north-west of the Cotteswold escarpment according to the theory, the Jurassic rocks should dip differently from what they do to the south-east thereof. A very little upheaval should have put them level; a little more, enough to make an anticline sufficiently important for Mr. Strahan's purpose, should have given the Jurassic rocks a decided tilt to the north-west. But the facts are all the other way: the Jurassic rocks of the Severn-Avon valley dip persistently to the south-east; they dip just as the Oolitic rocks of the Cotteswolds do. To postulate an anticline in the face of these facts ought to require a robust imagination; and it hardly seems desirable for anyone possessed thereof to label other theories which do at any rate fit such facts as these.

Suppose, however, that spite of the dip we grant the required anticline. What happens? Mr. Strahan says, "On the west side [of the anticline] the rivers are deflected to a south-westerly course as in the case of the Avon and Severn, or to a north-easterly course as in the case of the Ouse and Nen" (p. 220). Why the Ouse and Nen, when they rise behind, that is to the east, of where the supposed anticline would have run? It sounds rather haphazard, this parting of the waters. But of course Mr. Strahan has carefully considered what this statement involves before making it. When the rivers come into the syncline, which must of necessity lie to the west of the anticline, they still obey the law of gravity as to their further course. Some flow north-east, some south-west; therefore the syncline must have dipped in these two directions from a central axis in order to produce this phenomenon. Here, then, is another anticline to be accepted, one that must have been approximately at right angles to the other, a Charnian anticline this time. Mr. Strahan does not say anything about, nor offer any evidence for, its existence; yet logically such an anticline is an absolute necessity to justify his statement.

Suppose we accept both these anticlines and see what the position would be. We have a Caledonian anticline with a syncline to the north-west of it; this syncline dipping south-west and north-east from a Charnian anticline. The Caledonian anticline must have been similarly affected. Let us consider the Severn-Avon part. We have on the south-east of these rivers an anticline running approximately from north-east to south-west, and its axis dipping south-west, according to the necessities of Mr. Strahan's hypothesis. What happens? Observations on any good road which runs downhill will tell us. The crown of the road is the anticlinal axis, dipping downhill; the gutter between the road and the path is the syncline, dipping similarly. From the crown of the road and from the path the water cuts channels to the gutter, not at right

angles, as it would if the axis were level, but in a direction intermediate between the dip of the longitudinal axis and the dip from the crown to the gutter (Fig. 1).

The same thing is shown even better in a courtyard as regards synclinic drainage. I have in mind the Close at Gloucester, where there is a dipping syncline such as B, with oblique lateral channels like D′, D″. These artificial cases would have shown Mr. Strahan that his river drainage should be on the same plan. But he could have verified them by actual examples of river drainage; as regards the anticline, how off the north side of the Mendip axis, which runs approximately west to east with east dip, the streams flow north-eastward,[1] or how off the east side of the Pennine axis the streams like the Swale, Ure, Nidd, Wharfe, and Aire drain approximately south-eastward. Or, as regards a syncline, how, in that to the north of the Pewsey axis, the streams from north and south run obliquely to meet in the synclinal trough of the Kennet-Thames.



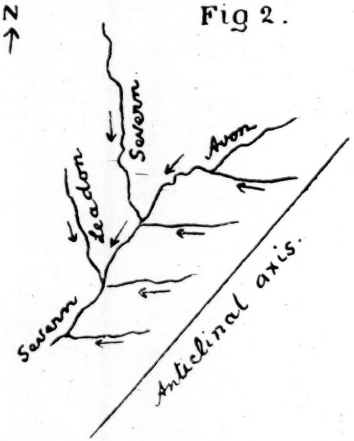


Fig. 1.—Drainage of a road and path. A, the crown of the road—the anticlinal axis, dipping south-east; B, the syncline—the gutter between the road A and the path C; D, D′, streams draining off the dipping axis at oblique angles; D′, D″, streams obliquely joining the synclinal or trough stream of the gutter.

Fig. 2.—Direction of tributaries on the left bank of Severn-Avon, to fulfil Mr. Strahan's hypothesis.

Examples of drainage show conclusively, then, that Mr. Strahan's river-system should have been after the manner depicted in Fig. 2; the tributaries draining his supposed anticline should have flowed obliquely. But the facts are against him: the tributaries on the left bank of the Severn-Avon have not the direction which his hypothesis requires; but they flow in a peculiar manner, more or less against the direction of the Severn and Avon (Fig. 3).

Now these tributaries diverge more or less from a central point;

[1] S. S. Buckman, "Excursion to Dundry": Proc. Geol. Assoc., 1901, vol. xviii, pt. 4, p. 157, fig. 9.

they diverge towards the main stream instead of converging. There are two explanations of such divergence, one where streams rise from a central domelike elevation and flow off in a radial manner; such, I presume, is the drainage of Dartmoor. But there is no evidence for any domelike elevation in the north-west Cotteswolds, and moreover the other rivers of the district do not accord therewith. That explanation cannot be right here. The other explanation may be tried, it is more elaborate. It is that these tributaries of the Severn-Avon have worked back in and now occupy valleys which were originally marked out by streams that flowed in the opposite direction, namely, with the dip, before the Severn valley had been made, and these streams converged to join the Thames river-system.

This theory, says Mr. Strahan, transgresses the limits of legitimate speculation. At any rate, however, it has the merit of agreeing with facts, such as those of the dip, of the breaches in escarpments, of the river distribution; and it gives a logical explanation of river phenomena. It supposes an original river-system flowing off the Palæozoic rocks of Wales on to the Secondary rocks of England, cutting channels in Oolites and Chalk on its way to the sea. An analogous condition of affairs in the case of the river-system of the east side of the Pennine range can be pointed to.

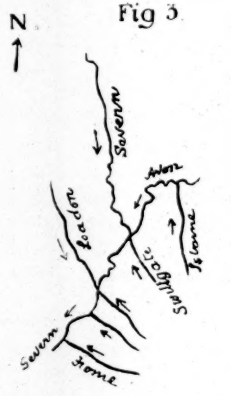


Fig 3

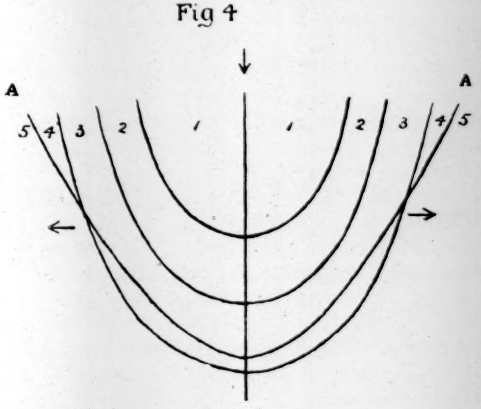


Fig 4

Fig. 3.—Actual directions of tributaries on left bank of Severn-Avon.

Fig. 4.—A south-dipping Malvernian anticlinal axis — outcrop of beds 1–4 after denudation. A, A, line of outcrop of covering bed 5 after a second uplift and denudation.

The main features of the theory, rivers flowing with the dip, the effect of differential denudation, river growth and river capture, had occurred more or less independently to various observers. To Professor Davis belongs the great merit of bringing the ideas as it were to a focus, giving them practical application, working out a definite theory, and especially pointing out the evidence for river capture. Following his lead again, I may now give the theory application to the district under discussion, and a little elaboration

at the same time. The theory postulates for its main features two well-known anticlinal systems, the backbone of Wales, with approximately north-south direction, dipping south towards the syncline connected with the South Wales Coalfield, and the South Wales-Mendip-Pewsey-Wealden anticline, with approximately west to east direction, dipping east. Minor anticlines may be disregarded for the present.

When an anticline of Malvernian direction dips south and is denuded the lines of outcrop converge southwards (Fig. 4, 1–4). If this denuded anticline be covered by a later deposit, be again uplifted, and denuded, the line of outcrop of the later deposit will diverge more from south to north than those of the earlier deposits (Fig. 4, A, A). The same laws will apply to an Armorican axis dipping east—turn the apex of Fig. 4 to the right hand. When one anticline is crossed by another denudation will give circular to ellipsoidal lines of outcrop, the latter shown almost perfectly in the structure of the Weald.

Fig 5.

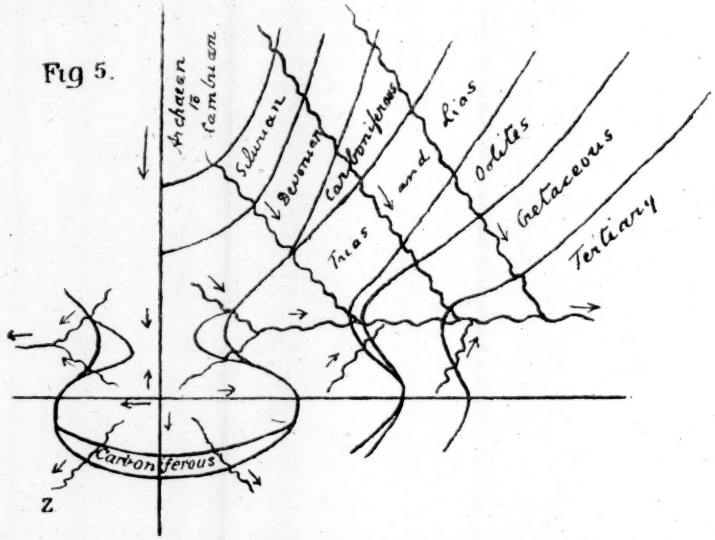


FIG. 5.—Combination of south-dipping Malvernian axis and east-dipping Armorican axis, showing the rock outcrop which would be produced and the dip streams which would be initiated. The wavy lines represent the streams. Z, the stream which developed to become the Severn. (Anticlinal axis not necessarily equal-sided.)

Here I may remark that a good example of a system of anticlines crossing one another at right angles, and also of curving anticlines on account of lateral thrust, is shown in the mosaic floor of the central hall of the Natural History Museum, South Kensington.

Taking the two anticlines of Malvernian and Armorican directions, with their respective south and east dips, combining them according to the principles laid down, allowing for three main overlaps—

post-Carboniferous, post-Jurassic, post-Cretaceous—we obtain a rock-structure with lines of outcrop arranged as in Fig. 5. Then, if we fill in the names of the various rocks, we shall see that it gives us what may be called the fundamental plan of the geological structure of Mid-Wales, Mid-England. In a generalized way it accords with the geological map; its discrepancies therefrom are no more than the omission of minor local anticlines would account for, together, of course, with local curvature of anticlines.

One point before proceeding further. Apparently Caledonian and Charnian directions of strikes and folds are not strictly due to impulse at right angles to the respective directions, that is, from north-west or north-east, but they are the immediate result of a combination of the north and south with the east and west lines of foldings which are dominant in the Eastern Hemisphere. With a Malvernian axis dipping south, Caledonian direction is given to the outcrop of beds on the east, Charnian to those on the west. With an Armorican axis dipping east, Charnian direction is given to the strata on the north, Caledonian direction to the strata on the south.

We have already seen that, from a dipping anticlinal axis, streams run in an oblique direction. Therefore, from the east of the south-dipping Welsh backbone the streams would first run obliquely—that is, in a south-east direction—at right angles to the Caledonian strike. From the north of the east-dipping Mendip-Pewsey axis the streams would run north-eastwards at right angles to the Charnian strike. In all cases the less the axial dip the less the oblique direction. Then these two series of dip streams would meet together in the synclinal trough north of the Mendip-Pewsey axis, in the line of the Kennet-Thames: that is a trough stream. Such is the initial stage of river development.

The second stage commences when the covering rock, whatever it may be, has been stripped off enough to expose the outcrops of older rocks; then differential denudation begins; the soft rocks are denuded faster than the hard ones, so that the latter are left to form escarpments. Strike streams are started along the outcrops of soft rocks; the growth of strike streams results in river capture. There is no better illustration of that than the manner in which the dip streams of the Cotteswolds are caught by the strike stream which has developed along the line of soft rocks in the Vale of White Horse.

The third stage follows on the capture process—rivers working back against the dip are started in the valleys of the beheaded dip streams. They necessarily follow up those valleys because those valleys are the lowest ground, made so by the original dip streams. So the phenomenon of breached escarpments with the water-parting in the low ground of the valley and streams flowing in opposite directions from that parting is seen to be exactly the result of the course of events here detailed.

What is to a certain extent abnormal, so far as the Severn is concerned, is the fact of its being an invader in what is strictly

Thames territory. It has come from west of the line of the Welsh backbone, and has broken into the Thames district. A stream such as that marked Z in Fig. 5 would have eaten its way back through the anticlines bounding the Thames Basin, because of its ability to give a quicker fall in a shorter distance; when it got past the anticlinal axis and into the soft Trias-Lias territory its course would have been easy. On the phenomenon of river-robbery in connection with an anticlinal axis I have given some details in the paper condemned by Mr. Strahan, dealing with the Salisbury Avon and the Pewsey anticline (Proc. Cotteswold Club, 1900, vol. xiii, p. 186). I have there shown that above-ground robbery is not the sole method of conquest; underground robbery is an important feature, preparing the way for the former.

One recommendation of the theory which I have very shortly epitomized is that its principles are applicable to all river-systems; whereas Mr. Strahan's hypothesis would only account for an isolated case. He could not bring in an anticline to account for every strike stream, nor for every case where the water-parting happened to coincide with the escarpment. So he would have to bring forward other hypotheses; and to have to account for similar phenomena by different hypotheses always seems rather dubious.

The river-system of the Paris Basin, for instance, can, in the light of the theories of Professor Davis, be read just as easily as that of the Thames. There are the dip streams, such as the Seine and its neighbours, draining from Palæozoic rocks across the outcrops of the Secondary strata into the Tertiary Basin. Then there is an invader from the outside comparable to the Severn, namely, the Loire, which has broken through the Palæozoic rocks in the west, has found its way into the Seine area, and has, at Orleans, captured the Upper Loire, which was evidently once a river of the Paris Basin system.

And now, leaving it to be judged whose theories transgress the limits of legitimate speculation, perhaps I may be allowed in conclusion to pen a few axioms of river development which do not seem to be rightly understood.

Differential denudation has so altered the face of the country that what appears now as an easy course for a river would have been impossible when the river started.

Escarpments are produced by the removal of material. This is self-evident; but the logical consequences do not seem to be appreciated—that the escarpments were not in existence when the rivers were initiated, and therefore they would not have formed any barrier to the river course, much less the formidable barriers which they now seem.

Streams which run down a slope or along a sloping trough, that is, dip streams and trough streams, are the only two kinds of rivers that are produced *ab initio*. Strike streams and anti-dip streams cannot be produced by water running off the original slope; they are only produced on the secondary slope which results from river erosion, and they have to grow by eating backwards.

Therefore, the Thames cannot be given a strike course into the

Wash, as was suggested, I think, by Prestwich; that would be equivalent to expecting a river to run along the level instead of down the slope; nor could the Upper Severn be given an original course into the Dee, suggested by Professor Lapworth, that would be almost equivalent to asking it to run uphill.

Rivers may abandon the hard course for the easier one, but not the easy one for the difficult. If the Thames had originally gained the sea by the Wash, and the Upper Severn got to the Dee, some particular damming-up theory has to be put forward to account for their leaving these easy courses to cut through the Chalk or Silurian barriers respectively. That is to say, abnormal conditions have to be postulated to explain a common and normal phenomenon. And when these conditions are applied to other cases they fail. Applied to the Weald they would mean that the drainage originally escaped *viâ* Hastings, then that this outlet was blocked in such a peculiar manner as to cause the drainage to cut several separate and independent channels through the Chalk to the north and south of the Weald!

VII.—Origin of the Crystalline Limestones of Ceylon.

By A. K. Coomáraswámy, B.Sc., F.L.S., F.G.S.

IT is generally supposed that the crystalline limestones which occur amongst the schists, associated with orthogneisses, in various parts of the world, are altered sedimentary limestones whose accessory minerals and crystalline structure have been developed by simple contact and dynamo-metamorphism; and no doubt many crystalline limestones are of sedimentary origin, and owe their peculiarities to these agencies. In other cases the peculiar mode of occurrence of such rocks or their manner of association with igneous rocks (orthogneisses or nepheline-syenites) has led to the suggestion of other theories.

Professor Högbom [1] has described the crystalline limestone which is associated with the elæolite-syenite of Alnö, where all transitions occur from pure limestone to calciferous and normal elæolite-syenite. Intergrowths of calcite with nepheline, ægirine, and felspar were noted. Professor Högbom (p. 109) thinks that, whatever the origin of the limestone (it seems not likely to be an altered sedimentary one), it is quite certain that it has been melted and taken up by the magma on a large scale without decomposition, and that on consolidation, calcite has crystallized out of the magma in just the same way as the other minerals.

Professor Judd [2] has suggested that the crystalline limestones of Burmah (which in many respects very closely resemble those of Ceylon) result from the alteration of the basic lime-silicates of the pyroxene-gneisses. My observations show that this is a theory not applicable to the crystalline limestones of Ceylon. This is shown by the field relations and by the fact that the Ceylon granulites are

[1] Geol. Fören. Stockholm. Förh., 1895, vol. xvii, pp. 100 and 214.
[2] Phil. Trans. Roy. Soc., 1896, vol. clxxxvii A, pp. 151–228.

almost always exceedingly fresh. The calcite and lime-silicates found near the junctions are not the result of alteration of minerals composing the granulites. Contact-metamorphic relations between the limestones and granulites are everywhere indicated.

Dr. Callaway has suggested that the crystalline limestones of Bodwrog and Porth Trecastell in Anglesey,[1] and of Ceylon,[2] may have originated by "segregation from plutonic rocks during deformation." That the Ceylon limestones have not been formed thus is shown by the contact-metamorphic relations between them and the granulites, and the freedom from deformation of the latter, with which they are inseparably associated.

Mr. Holland[3] has suggested that the crystalline limestones of Burmah may have existed in a state akin to fusion. Calcite has been claimed as an original mineral in nepheline-syenite by more than one observer.[4] The present writer has described what is probably an original intergrowth of calcite with quartz.[5]

I have recently given some account of the crystalline limestones of Ceylon,[6] showing that a vast series of granulites, various in chemical and mineralogical composition, is there most intimately associated with a smaller but widely distributed series of crystalline limestones occurring in bands of various widths, whose foliation (dependent on variations in coarseness of grain, structure, and mineral composition) is parallel to that of the granulites and to the boundaries between the two rocks. The contact phenomena and the transitions between the two types of rock are also described.

As to the real *origin* of these limestones, not very much can be said. We might regard them as altered sedimentary or even tufaceous rocks, which the intrusive granulite has melted and partially absorbed. The wollastonite-scapolite gneisses of Galle might, on this supposition, result from the total absorption of a large mass of limestone by the granulites. It may be objected, however, that there is little or no evidence of the existence of other altered sedimentary rocks such as would probably have accompanied the limestone,[7] and that the limestones occur in different areas, sometimes abundantly and in wide bands, sometimes in narrow bands far removed from other rocks of the same sort.

[1] Rep. Brit. Assoc., 1887, p. 706.
[2] Geol. Mag., 1902, p. 285.
[3] Mem. Geol. Surv. India, 1901, vol. xxx, pt. 3, p. 175.
[4] Holland: Mem. Geol. Surv. India, loc. cit., p. 197. Adams: Amer. Journ. Sci., 1894, vol. xlviii, p. 14.
[5] Quart. Journ. Geol. Soc., 1900, vol. lvi, p. 606, also pl. xxxiii, fig. 1.
[6] Quart. Journ. Geol. Soc., 1902, vol. lviii, p. 399.
[7] I have met with rocks almost composed of dark mica in one or two localities (Yatirawana, near Wattegama, and Talbot Town, Galle) associated with the granulites. Almost any mineral occurring in the granulites may, however, be sometimes met with in this way as a main constituent of a local variety. It is, however, quite true that some varieties rich in garnet and biotite are not altogether unlike much altered sedimentary rocks, though I do not myself regard them as such. Lacroix has described some rocks in which andalusite, sillimanite, and corundum occur, but unfortunately the localities in Ceylon are unknown. Possibly these minerals indicate the existence of altered sedimentary rocks, but this is by no means necessarily the case.

Whatever their original character may have been, the limestones must have existed before the intrusion of the granulites. I think it is clear, however, that *in their present condition* the two rocks are 'contemporaneous,' and this is shown by their intimate associations and similar behaviour, and by the transitions from one rock to the other which sometimes occur. I suggest that the limestones themselves have existed in a state akin to fusion [1] and have behaved much as igneous rocks, and that the carbonates entering into the constitution of the granulites near the contacts are, as they appear to be, original minerals.[2] That the limestones have existed in a state akin to fusion is shown, I think, by the appearances of flow-structure (foliation),[3] the occasional porphyritic structure, the aggregates of accessory minerals (which correspond perhaps to the basic secretions of some igneous rocks), the intergrowths of calcite and dolomite, and by the field relations of the limestones and charnockite series. The accessory minerals have crystallized out as if from a magma. The limestones may have been softened before the intrusion of the granulites (which greatly exceed them in amount), or have become so as a result thereof. Each rock has been affected near the contact by the absorption of material from the other, the granulites showing the more conspicuous modifications. This transference of material is shown in the granulites near the junctions by the appearance of minerals rich in lime, such as scapolite, sphene, diopside, phlogopite, and calcite, and in the limestones by the appearance of minerals such as diopside, amphibole, phlogopite, and spinel, and very rarely scapolite and felspar. The common occurrence of spinel as a contact mineral seems to result from the appropriation of all available silica in the formation of lime-silicate minerals, leaving the oxides to form spinel.

The whole process must have taken place under conditions of great pressure. Differential movements during consolidation have produced the conspicuous foliation. To some extent the limestones and granulites have been rolled out together during consolidation, and in this way sills of granulitic rock in the limestone have been broken and portions separated, sometimes as lenticles continuing along the strike the unbroken portions of the sill, sometimes to form irregular patches or snaky twists of pyroxenic rock in the limestone, sometimes to be found as quite isolated masses, surrounded by the enclosing limestone.

To summarize, I wish to suggest—

(1) That contact-metamorphic relations between the limestones and the charnockite series are everywhere clearly indicated.

[1] The direct use of the term 'molten' is avoided, inasmuch as we can know but little of the conditions of matter under very great pressure, and it is inadvisable to use the same terms in the description of conditions which, though analogous, must yet be very different.

[2] Cf. J. J. H. Teall, Geol. Mag., 1886, p. 349.

[3] It is evident that the limestones have not (except very locally) suffered from deforming earth-movements since the development of the accessory minerals, whose varying abundance is largely the cause of the apparent foliation.

(2) That it is not altogether easy to regard the limestones as altered sediments.

(3) That whatever their origin they have actually existed in a state "akin to fusion," and as far as their present characters are concerned, are contemporaneous with the charnockite series.

(4) That limestones and the charnockite series have suffered but little from deforming earth-movements since their final solidification.

NOTICES OF MEMOIRS, ETC.

1. The International Geological Congress.—The next Session of this Congress will be held in Vienna from the 20th to 27th August, 1903. The Austrian geologists have appointed a committee of organization, which has just issued its first circular. The President is Dr. E. Tietze; the general secretary, Professor C. Diener; and the secretaries, Messrs. F. Teller, G. Geyer, and A. von Böhm. The circular contains a list of the excursions which it is proposed to arrange in connection with the Congress. The following are to take place before the Session:—1. Palæozoic region of Central Bohemia. 2. Hot Springs and eruptive districts in the north of Bohemia; and the surroundings of Brünn in Moravia. 3. Galicia, beginning with the coal district of Ostrau and the neighbourhood of Krakau and Wieliczka, then dividing into two sections, one of which visits the petroleum beds, and the other the peaks of the Carpathians and the Tatra Mountain. 4. Salzkammergut. 5. Styria. The following are to be after the Session:—6. Dolomites of the Tyrol. 7. Basin of the Adige in Tyrol. 8. Western region of the Hohe Tauern (Zillerthal Alps). 9. Central region of Hohe Tauern (Venetian Alps). 10. Predazzo. 11. The Carniolan and Julian Alps. 12. Glacial region of the Austrian Alps. 13. Bosnia and Dalmatia. There is also an invitation from the Geological Society of Hungary, which includes a visit to Buda-Pesth and the lower course of the Danube (Cataracts and Iron Gate).

2. Illustrations of Volcanic Phenomena.—There has been arranged at the British Museum a temporary exhibition to illustrate the recent volcanic eruptions in the West Indies, and their phenomena. Within about a fortnight of the eruptions in St. Vincent and Martinique, the Exhibition was installed in that gallery of the Geological Department in which other collections elucidating the dynamic side of geology are already displayed. Now, however, it is placed in one of the bays of the central hall, where it has attracted a large number of visitors. A general guide-label informs the visitor that the Exhibition is arranged in several sections which should be examined in regular order, as follows:—

A series of maps and diagrams, some specially prepared, shows the geography of the Lesser Antilles and the relations of their volcanoes to the general structure of the globe, particularly to the disturbed region of Central America. On these maps, pins have

been inserted drawing attention to places specially affected during the last few months. Adjoining this are pictures and photographs of the scenery, buildings, vegetation, and human inhabitants of the ruined islands. A noteworthy contribution to this section is the excellent series of sketches lent by the Rev. W. C. Bourchier, R.N. The recent elevation of the Antillean Ridge from great depths is illustrated by specimens of fossil animals and their recent congeners, specially selected for that purpose. Next follow specimens illustrating the volcanic geology of the Lesser Antilles, the dust from this and previous eruptions being, of course, exhibited and explained. We understand that arrangements have been made to acquire further specimens of volcanic ejectamenta from Martinique and St. Vincent. The next section illustrates the fauna and flora of the Lesser Antilles, attention being specially directed to such species as are exceedingly rare (possibly owing to the effects of previous catastrophes) and whose extermination is feared, also to species characteristic of the islands and, as such, mentioned in the accounts of travellers. The portion of the Exhibition having special reference to the Lesser Antilles is concluded by a series of extracts from local newspapers and other notes having reference to present and previous eruptions in that region. The remainder of the Exhibition deals with volcanic phenomena generally: first, by means of a large series of plates and photographs ranging from the sixteenth century to the present year, and representing many of the best known volcanoes of the globe, as well as some of the extinct or possibly dormant volcanoes in various parts of the world; secondly, by a typical series of volcanic products, carefully labelled for the benefit of the public. Dr. Bather and Mr. Prior are responsible for this exhibition.

3. Natural Science Records.—The Geological Record, the Annuaire Géologique, the Annals of British Geology, not to mention less ambitious attempts, having had their day and ceased to be, and the Record of Geological Literature added to the Geological Society's Library having entered on a period of æstivation, it may be of service to indicate yet another bibliography, the "Revue Bibliographique des Sciences naturelles pures et appliquées . . . publiée par J. Chavanon et G. Saint-Yves. . . . Paris, 45, Avenue Ledru-Rollin."

The *Revue* is announced to appear in monthly parts of five or six octavo sheets, at a subscription price of 30 francs for addresses in the Postal Union.

The programme is far too large to be filled with any success in an annual volume of such restricted size; but by devoting special attention to Agronomic Science the promoters will fill a gap. We cannot say the same for the second feature on which they pride themselves, namely, the indexing all names of new genera and species, or species from new localities, since this is already performed by the Zoological Record and by the Concilium Bibliographicum, Zurich, which two bibliographies supplement each other's inevitable deficiencies. Under each of the main headings—Geology, Mineralogy and Mining, Zoology, Anatomy, and so forth—is given

an annotated list of the contents of certain parts of a number of periodicals, taken by countries. Each number is completed by an index to the subject-matter and a list of the periodicals noticed in that part. This latter is a useful feature.

4. Dr. F. A. Bather, M.A.—On April 23 the Principal Trustees of the British Museum appointed Dr. F. A. Bather to fill the Assistant-Keepership of the Department of Geology, rendered vacant by the promotion of Dr. A. Smith Woodward to the Keepership on the 18th December previous.

5. Earthquakes in Greece.—It may not be generally known that there is published a list of earthquakes observed in Greece for the year. The list appears in *Annales de l'Observatoire Nationale d'Athènes*, edited by Professor Démétrius Eginitis. Volume iii, 1901 (4to, *Athènes*), contains the earthquakes recorded for the year 1899, in chronological orders. In each case the time is given, its strength noted, direction, length, and the name of the recorder. The utility of this valuable record would be much enhanced if Professor Eginitis would give an alphabetical index to the localities in future lists.

6. Emendations of Ammonite Nomenclature.—Under the above title, Mr. S. S. Buckman has issued an 8 pp. pamphlet of revision of the nomenclature in his monograph on the Inferior Oolite Ammonites published by the Palæontographical Society. The pamphlet, at first issued privately in June, has now (July) been published, and is on sale at Norman, Sawyer, & Co., Cheltenham, price one shilling. It contains numerous new generic and trivial names.

REVIEWS.

Aids in Practical Geology. By Professor Grenville A. J. Cole, M.R.I.A., F.G.S. 4th edition. 8vo; pp. 431. (London: Charles Griffin & Co., 1902.)

WE were able to speak highly of this "eminently practical" work on geology eleven years ago in our notice of the first edition (Geol. Mag. for 1891, p. 230). We therefore welcome the fourth edition, for it proves that the labours of the author have been appreciated. Those of our readers who have not yet acquired the book should know that it does not deal with economic geology, but is intended as a companion to ordinary textbooks, and to give instruction to the student in the methods of examining and determining minerals, rocks, and fossils. The work has been revised throughout, and amongst the fresh information mention should be made of that on the isolation of the constituents of rocks. The author observes that "Few changes in nomenclature have been introduced into this edition, and the limits of the names of rocks, and even of fossil genera, have been kept as wide as possible." This is right. Nomenclature is the bane of students and of teachers of natural science, in respect of its 'kaleidoscopic' changes; and Professor Cole has not been able to escape them altogether.

We cannot think he has acted wisely in substituting De Lapparent's 'Gotlandian' for Upper Silurian. The student should be taught to use the generally accepted terms. Silurian drops out entirely from Professor Cole's Table of Formations (p. 293).

REPORTS AND PROCEEDINGS.

Geological Society of London.

June 11th, 1902.—Professor Charles Lapworth, LL.D., F.R.S., President, in the Chair.

Professor Bonney exhibited a mounted specimen of the volcanic dust which fell on the deck of the steamer *Roddam* during the great eruption of Mont Pelée on May 8th, for which, as well as for another from the Soufrière of St. Vincent, that had fallen in Barbados, he was indebted to Sir William Crookes, F.R.S. The dust from Mont Pelée consists of fragments of minerals and rock (the former, perhaps, slightly in excess of the latter), very commonly about ·007 to ·008 inch in diameter, but ranging from about ·005 to ·01 inch. A very little fine dust had been removed by levigation before mounting the specimen. The minerals are:—(1) Chips of felspar sometimes bounded by cleavage-edges, occasionally showing oscillatory twinning or zonal structure. The refractive index and extinction-angles suggest that the majority are labradorite. Some contain minute acicular microliths or small brownish enclosures (? vitreous), which now and then are regular in form and arrangement, like negative crystals, and not seldom contain little bubbles. (2) Pyroxene, occasionally with cleavage-edges, or even idiomorphic, generally of a light bottle-green tint. There are certainly two species: one showing a distinct pleochroism from green to brown with straight extinction—a variety of hypersthene; the other barely pleochroic, with an extinction that proves it to be augite. He could not identify with certainty magnetite or any other mineral. The rock-fragments are chips of a brownish, often dirty-looking glass, with small cavities, sometimes showing microliths or adhering to minerals; much of it opaque, or nearly so, with transmitted light, and a brownish-grey by reflected light, once or twice reddish. As Dr. Flett gave an excellent description of the Barbados dust from the Soufrière at the previous meeting, the present speaker thought that he need say no more than that in the specimen now exhibited the fragments seem a shade smaller, and minerals are slightly more abundant, especially pyroxene, than in the Mont Pelée dust.

Notwithstanding the risk of generalizing from a single slide, Professor Bonney inferred that the ejecta of the two volcanoes are generally similar. Both, compared with specimens in his cabinet from Cotopaxi, are more uniform in size. The travelled dust from the Soufrière is a little smaller than that from the actual summit of the Andean volcano, but coarser than similar material from Chillo (over 20 miles), Quito (35 miles), Ambato (45 miles), Riobamba (65 miles), and the summit of Chimborazo, about the same.

All these vary much more in size and run distinctly smaller, especially the last.[1] That from Mattakava, Hick's Bay, New Zealand (fallen on June 16th, 1886), is rather coarser, more scoriaceous, with fewer mineral fragments (especially of pyroxene), to which a dirty glass is often adherent. The dust from Barbados, ejected by the St. Vincent Soufrière in 1812, is very much finer-grained, but contains the same minerals, though pyroxene is less abundant. In neither had he found the clear glassy pumice described by Miss Raisin [2] from the marls of that island.

The following communications were read :—

1. "A Descriptive Outline of the Plutonic Complex of Central Anglesey." By Charles Callaway, D.Sc., M.A., F.G.S.

The central complex of Anglesey was originally composed of diorite, felsite, and granite. The gneiss and granitoid rock of the area, formerly regarded as sedimentary in origin, are now known to be plutonic masses. The diorite undergoes numerous modifications, into hornblende-gneiss, chlorite-gneiss, micaceo-chloritic gneiss, and kersantite and biotite-gneiss. The felsite has not been found in its original state, but is converted into 'hälleflinta,' quartz-schist, mica-schist, and mica-gneiss ; granite and quartz felsite are intrusive into the diorite and felsite, and the two former are regarded as derived from the same magma. They are not foliated, and were intruded subsequently to the modification of the diorite and felsite into gneisses and schists. The diorite, originally a zenolith surrounded and injected by granite, has been modified into an elliptical dome of dark gneiss; into simple gneisses by pressure, and into complex gneisses by pressure *plus* granitic intrusion. This intrusion has often produced fusion at the contact, sometimes with the generation of biotite in the diorite. In addition to this, the diorite possesses an imperfect fluxion-structure.

2. "Alpine Valleys in relation to Glaciers." By Professor T. G. Bonney, D.Sc., LL D., F.R.S., F.G.S.

The author discusses some hypotheses about the formation of Alpine valleys which have been advanced by Professor W. M. Davis, but has left the Ticino Valley, on which the latter lays much stress, to Professor Garwood, who has very lately visited it. Professor Davis maintains that the upper and wider parts of Alpine valleys were excavated in pre-Glacial times, the lower and narrower portions during the Great Ice Age. The author tests this hypothesis by applying it first to the valley of the Visp, of the eastern arm of which, and of the 'hanging valley' like a gigantic corrie, where Saas Fee is situated, he gives a description, pointing out that all parts are so connected that any separate explanation of their form is impossible.

To obtain an idea of the condition of the Alps in Middle and Later Tertiary times, we may consider the effect of alterations of temperature, on the assumption (which, as he shows, is not likely to

[1] All these (collected by Mr. E. Whymper) are described in Proc. Roy. Soc., vol. xxxvii (1884), pp. 114 et seqq.

[2] Quart. Journ. Geol. Soc., vol. xlviii (1892), pp. 181, etc.

be seriously incorrect) that the altitude of the Alps during the greater part of their existence has remained unchanged. A rise of temperature of from 6° to 7° Fahr. would have the same effect as lowering the district by 2,000 feet; a rise of 10° would correspond with 3,000 feet. In the latter case the Pennine chain about the headwaters of the Visp would be comparable with the range from Monte Leone to the Ofenhorn. With a rise of 14° glaciers would almost vanish from the Alps, for the snow-line would then be at 12,000 feet above sea-level. Thus glacial action in the Oligocene and Miocene ages would be a negligible quantity, and it would gradually become sensible during the Pliocene; but glaciers would not invade valleys now free from them until the temperature was some degrees lower than it is at present—in other words, can have only occupied these during a small portion of their existence.

The author passes in review a number of other Alpine valleys, which lead to the same conclusion. He calls attention once more to the connection of cirques with valleys, to the impossibility of referring the former to glacial action, and to the unity exhibited by all parts of the Alpine valleys, touching upon some structural difficulties which Professor Davis has been content to meet with hypotheses. Alpine valleys in all parts, as the author shows, indicate by their forms meteoric agencies other than glaciers, which can only have acted for a comparatively short time and have produced little more than superficial effects.

3. "The Origin of some 'Hanging Valleys' in the Alps and Himalaya." By Prof. Edmund Johnstone Garwood, M.A., F.G.S.

Lateral valleys which enter the main valley marked by discordant grades in the Jongri district of the Sikhim Himalaya have been attributed by the author to Pleistocene elevation and super-erosion of the main valley by water. Similar valleys in the Val Ticino have recently been attributed to overdeepening of the main valley by ice. The author shows that there is no real proof of this; in fact, the evidence seems strongly to point to fluviatile and not glacial erosion of the main valley. This is shown by the overlapping profiles and river-gorges situated both above and below some of these 'hanging valleys,' and by the fact that a greater relative amount of erosion has taken place towards the upper end of the main valley than at the lower, where the mouths of the 'hanging valleys' are less elevated. The overdeepening of the main valley is attributed to an epeirogenic uplift in Pleistocene times, consequent on the melting away of the ice-cap, the lateral valleys being merely tilted sideways. This effect is intensified by the protection accorded to the high lateral valleys by ice, which even nowadays still lingers there. Examples from the Maloja district of the Engadine are cited as confirmatory of this. The best preserved of these 'hanging valleys' in three districts examined by the author all face north-eastward, and show protection by ice; others not so protected have begun to cut back their gorges to an accordant grade with the main valley. Examples of other types of 'hanging valleys' not due to the overdeepening of the main valley are given, and proofs of the greater power of water to excavate over ice are assigned.